THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. V.—MAY, 1917.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Henry Fairfield Osborn, LL.D. (Princeton, Columbia, Hartford), Sc.D. (Cambridge, Princeton), Ph.D. (Christiania), A.B. (Princeton); Foreign Member of the Linnean and Geological Societies of London; President of the American Museum of Natural History, New York.

(WITH PORTRAIT, PLATE XII.)

FOR nearly half a century geologists have followed with great interest and admiration the discoveries of fossil vertebrate animals in the west of North America. From the early days when western pioneers brought back scattered fragments for study by Leidy, to the seventies and eighties of last century when Cope and Marsh led or encouraged adventurous expeditions to collect fossils in the territories then occupied by hostile Indians, the continual succession of new forms of extinct reptiles, birds, and mammals met with in an unusual state of preservation, excited increasing attention. So remarkable, indeed, were these finds and so sporting was their pursuit, that rivalries arose and passed beyond the state of friendly emulation which is good for real progress. It was thus fortunate for American palæontology that a younger generation of well-trained enthusiastic students was then ready to enter the field, and especially fortunate that their leaders were imbued with a harmonious spirit of co-operation. Among these leaders was the subject of our present biographical sketch, who has perhaps done most by his personal influence to maintain the happy relations which now exist between all workers in vertebrate palæontology in America.

Henry Fairfield Osborn was born on August 8, 1857, at Fairfield, Connecticut, and began his education at the Lyons Collegiate Institute, New York. He next proceeded to Princeton University, where he graduated as A.B. in 1877. In 1879–80 he followed post-graduate studies under F. M. Balfour at Cambridge, and under Huxley at the Royal College of Science, London. In 1881 he became Assistant Professor of Natural Science at Princeton, and from 1883 to 1890 he was Professor of Comparative Anatomy in the same University. In 1891 he removed to New York, where he had been appointed Da Costa Professor of Biology in Columbia University and Curator of Vertebrate Palæontology in the American Museum of Natural History. In 1896 his Professorship was restricted to Zoology alone, and in 1910 he resigned both this and his Curatorship, being nominated Research Professor of Zoology in Columbia

University. In 1901 he was elected a Trustee of the American Museum of Natural History, and was second Vice-President from 1901 to 1908, when he assumed his present office of President of the Board of Trustees. In 1900 he succeeded Professor O. C. Marsh as Vertebrate Palæontologist to U.S. Geological Survey, and from 1900 to 1904 he was Vertebrate Palæontologist to the Geological Survey of Canada in succession to Professor E. D. Cope. In 1906 he was offered but declined the Secretaryship of the Smithsonian Institution, Washington.

Professor Osborn was specially trained as a zoologist, and several of his earlier papers relate to the structure and development of the brain. In association with his fellow-student, William Berryman Scott, however, his interest was soon aroused in extinct animals by the discoveries of Cope and Marsh; and in 1877 he began his life-work in palæontology by joining Scott and Francis Speir, jun., in an expedition to collect mammalian remains from the early Tertiary formations of Wyoming. On his second collecting trip in 1879, in the Washakie Eocene Basin of Wyoming, he recognized the possibility and importance of making more exact stratigraphical records than had previously been attempted; and from that time onwards he, with his pupils and associates, has paid so much attention to the stratigraphy of the deposits yielding vertebrate fossils, that the order of succession in each region explored is no longer a matter of inference and speculation but a definitely ascertained fact. It has thus become possible to use successive groups of vertebrate fossils with confidence when tracing changes in their peculiar characters through geological time; and many phenomena have become clear which would otherwise have been overlooked.

The precise determination of the relative ages of the extinct mammals in North America naturally suggested a reconsideration of the mammal-bearing Tertiary deposits in the Old World, and between 1898 and 1900 Professor Osborn obtained the help of several European palæontologists in preparing a table of "Correlation between Tertiary Mammal Horizons of Europe and America". As discoveries progressed he continued to improve this correlation, and it was extended and brought so far as possible up-to-date in his handsome volume, *The Age of Mammals in Europe, Asia, and North America*, published in 1910. In connexion with these researches it is interesting to note that in 1900 Professor Osborn reached the conclusion that the common ancestors of the Proboscidea, Sirenia, and Hyracoidea would be found in Africa—a conclusion that was immediately afterwards confirmed by the discoveries of Dr. C. W. Andrews and Mr. H. J. L. Beadnell in the Egyptian Fayum.

In his long series of descriptive papers and memoirs Professor Osborn has dealt with almost all groups of mammals and reptiles, but special reference may be made to his important contributions to our knowledge of the Rhinoceroses, Horses, Titanotheres, and Dinosaurs. For the last fifteen years he has been occupied with a Monograph of the Titanotheres, which will shortly be published by the United States Geological Survey. For ten years he has also been accumulating notes for a similar Monograph of the Sauropodous

Dinosaurs. His most recent memoirs include those on the gigantic carnivorous Dinosaur *Tyrannosaurus* and on the integument of the Iguanodont Dinosaur *Trachodon*, both astonishing discoveries.

While engaged in descriptive work, Professor Osborn has always been keenly appreciative of its philosophical bearings, and he has published many dissertations on the transmission of acquired characters, mutations, adaptive variations, and allied subjects. In 1894 he contributed to the Columbia University Biological Series an important volume entitled *From the Greeks to Darwin*, which has been several times reprinted, and has also been translated into Italian. He discussed "Darwin and Palæontology" in the volume on *Fifty Years of Darwinism*, published by the Cambridge University Press in 1909. He stated the biological conclusions drawn from his study of the Titanotheres in a paper read before the National Academy of Sciences in 1911; and more recently he addressed the Paleontological Society of America on the "Origin of Single Characters as observed in Fossil and Living Animals and Plants".

Finally, Professor Osborn has made many valuable contributions to popular scientific literature, and among the latest may be mentioned his profusely and beautifully illustrated volume on the *Men of the Old Stone Age, their Environment, Life, and Art*, which was published at the end of 1915.

During the greater part of his career Professor Osborn has been much occupied with administration in varied ways. From 1892 to 1895 he was Dean of the Faculty of Pure Science in Columbia University. Since 1881 his organization, in connection with the American Museum, of a complete survey of the geological succession of the higher vertebrates in North America, has produced a flourishing school of vertebrate palæontology, represented by Earle, Matthew, Granger, Gidley, Loomis, Brown, Lull, Peterson, Gregory, and others. In 1896 he took a very active part in the foundation of the New York Zoological Park, under the auspices of the New York Zoological Society, of which he has been President since 1909. He is also a leading member of the New York Academy of Sciences, over which he presided in 1898–1900; and he has been a Trustee of the New York Public Library since 1912. Among other offices, he has held the Presidency of the American Morphological Society (1897), the Marine Biological Association (1898–1900), the Audubon Society (since 1910), and the American Bison Society (since 1914). Finally, in 1914, he became a member of the Belgian Relief Committee.

Professor Osborn has naturally received many honours both at home and abroad. He has been admitted to several university degrees already enumerated, and in 1914 he was awarded the Hayden Gold Medal by the Philadelphia Academy of Natural Sciences. He is a Foreign Member of the Linnean and Geological Societies of London, the Cambridge Philosophical Society, the Manchester Literary and Philosophical Society, and the British Association. From frequent visits, indeed, he is almost as well known to the scientific men of this country as to those of America, and his personal charm has won for him a large circle of devoted friends. Those who have visited him in his beautiful home amid the

wooded heights at Garrisons-on-Hudson, have learned to appreciate the reasons for his success as a leader of men. He is a most unassuming student in the happiest circumstances, ever eager for the promotion of natural knowledge, and watchful to make the best use of all opportunities. To our tribute of admiration we would only add our best wishes for his continued enjoyment of health and strength long to carry on the work for which geological science is already so much indebted to him.

A. S. W.

II.—Morphological Studies on the Echinoidea Holectypoida and their Allies.

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

(PLATE XIII.)

II. The Sunken Tubercles of *Discoides* and *Conulus*.

1. Introduction.

In 1914 I published, in this Magazine, an account of "Some Problematical Structures in the Holectypoida", indicating therein the presence of certain sunken features on the test-surface of "*Pygaster*" (*Plesiechinus*), *Coenholectypus*, and *Discoides*. Two series of depressions were described, of which one was wholly sutural in position, while the other was situated on the adoral ambulacral plates, and consisted of more or less sunken tubercles or granules. It is with the latter series of structures that the present paper deals. Although the title "problematical structures" remains appropriate, further work and more refined methods of preparation have made possible a more accurate description of them, and have considerably increased the area of their known distribution. Save for comparisons and passing references, the development of depressions on the tests of the Pygasteridæ and Holectypinæ will not be considered here. In Jurassic times, when these two groups were at their prime (in this country at least), sunken tubercles were in an incipient stage of evolution, and are in consequence very difficult to distinguish from their normal associates. It is therefore safer to deal first with the well-matured structures, as developed in Upper Cretaceous times. Moreover, the condition of preservation, and especially the character of the matrix, of Chalk fossils, make it easier to clean and stain the specimens without much risk of damage to delicate surface features. A test that has been naturally exposed by weathering is rarely serviceable for study of these structures, and more or less elaborate methods of staining and sectioning are necessary to render them sufficiently clear for accurate description. Small and inconspicuous as the depressions are, they nevertheless appear to have considerable phylogenetic and taxonomic importance. For their physiological value I have no suggestions to offer.

2. The Ornament of *Discoides cylindricus* (Lam.).

(a) *The Interambulacra of the Adapical Surface.*

An examination of an interambulacral plate midway between the apical system and the ambitus shows that the somewhat sparse and

inconspicuous ornament consists of no less than five different types (see Pl. XIII, Figs. 1 and 2).

The primary tubercles are set in shallow areolæ, and are arranged serially in a definite pattern (see Hawkins, Geol. Mag., 1911, p. 448). They are few in number and cover but a small proportion of the surface of the plate. The secondary tubercles are very small, but are fairly numerous. They are areolate, but some of them seem not to possess mamelons. At times they form rough rings around the primary areolæ, and occasionally take on an irregularly linear arrangement in a transverse or radiating direction. The greater number of them seem to be quite fortuitous in position, and they vary considerably in diameter. Still more irregular, both in distribution and size, are the miliary granules, which are present in about the same numbers as the secondaries.

In addition to these three normal types of ornament, destined for the support of primary and secondary radioles and pedicellariæ, are two more of quite different appearance. One of these series of "tubercles" superficially resembles that of the secondary tubercles. The structures are of about the same size, but differ in the comparative scarcity of the special series, and in the character of their areolæ. They are either flush with the surface of the test (though readily visible owing to their extreme smoothness), or more commonly, slightly *raised* above the surrounding level. In the centres of these smooth circular areas are placed minute and inconspicuous mamelons, which seem to be always imperforate. The mamelons rise from pits of very little greater diameter than themselves, and do not project above the level of their "areolæ" (see Pl. XIII, Fig. 5).

The other aberrant series consists of tubercles which may be of any size from that of a secondary to almost that of a primary, having small mamelons on bosses set in areolæ which are deeply, but not entirely, sunk below the plate surface. When a test has been stained with a granular substance, this type of ornament becomes very obvious through the accumulation of colouring matter in the hollows. Although many of the sunken tubercles are situated without apparent order, some few seem to be fairly constant in position on the serial plates of a column.

The former series of peculiar "tubercles" will be more fully described in the section of the paper dealing with *Conulus*, in which genus similar structures are much more strongly developed, but the latter series (apparently absent from *Conulus*) requires more precise analysis.

Except that the mamelons of the "sunken tubercles" seem to be usually, if not always, imperforate, the chief difference between these structures and the normal primary tubercles lies in the character of their areolæ. There seems always to be some sort of a boss on which the mamelons are placed, though there is hardly any indication of its base. The floor of the areola is inclined, to make an angle with the plane of the test-surface, and the inclination is always adoral and inwards. In most cases the adapical border of the areola is sensibly raised above the surrounding level. Thus the

axis of the tubercle (which is at right angles to the surface of the test in normal cases) slopes away from the apex downwards towards the ambitus (see Pl. XIII, Fig. 3). There seems to be almost perfect homogeneity among the sunken tubercles, apart from their variation in size.

On each of the first few plates from the apical system there is only one "sunken tubercle" (Fig. 1), constantly situated near the adoral transverse suture of the plate, and nearer to the interradial suture than the tubercle of the central (Cidaroid) series. This particular row of "sunken tubercles" can be distinguished, with but little variation in relative position, on all the interambulacral plates of the adapical surface except those immediately above the ambitus. Its members are commonly larger than the other less regularly disposed tubercles of the same type. The number of "sunken tubercles" on each plate shows a steady increase until just above the ambitus, but the depth of their areolæ shows a corresponding decrease. They never become very numerous. Although none of the additional "sunken tubercles" show any constancy of position comparable with that of the first-mentioned series, it is a general rule that the largest and most deeply excavate ones are situated near to, and sometimes in contact with, the adoral transverse margins of the plates.

A comparison of Figs. 1, 2, and 4 (Pl. XIII) discloses an interesting evolutional feature in connexion with the "sunken tubercles". In *Holectypus depressus* (the Cornbrash form, not that from the Inferior Oolite) there is one such tubercle on each of the interambulacral plates just above the ambitus, but never more than one. The plates near the apex are without any. This solitary "sunken tubercle" is in precisely the same relation to the central primary as it is in the adapical plates of *D. cylindricus*. Thus the "young" plates of the Cretaceous *Discoides* show the same development, in this respect, as the "adult" plates of the Jurassic *Holectypus*. The evidence for the phyletic continuity between the Holectypinæ and Discoidiinæ thus receives a convincing addition.

(b) *The Ambulacra of the Adapical Surface.*

The ornament of the ambulacral plates is on a smaller scale, and less thickly spread, than that of the interambulacrals, but it consists, none the less, of a corresponding series of five different structures. The primary tubercles are, on the whole, very regularly arranged in vertical series on every third plate. The secondary tubercles are few, and are usually associated with either a primary areola or a peripodium. The miliaries are very small, but are relatively numerous, and for the most part form transverse lines across the middle of each plate.

The two peculiar types of ornament are both present, the "raised secondaries" in fair numbers, and the "sunken tubercles" with much the same frequency for a given area as those of the interambulacra. I have never seen more than one "sunken tubercle" on an ambulacral plate. As in the interambulacra, there is one vertical series of these tubercles (situated near the peripodia) which

tends to occur regularly on every third plate. As the figures show (Pl. XIII, Figs. 1 and 2), the regularity is not perfect, but in a whole column the series of tubercles has an average number one-third that of the plates. There are very few "sunken tubercles" apart from this series. All are identical in structure with those of the interambulacra.

(c) *The Interambulacra of the Adoral Surface.*

On the adoral surface, and at the ambitus, the ornament of the interambulacra suddenly becomes coarser and more abundant. The primary tubercles increase in size, numbers, and prominence, and especially in the excavation of their areolæ. Although their arrangement is on the same plan as that of the tubercles of the adapical surface, a series of secondaries becomes enlarged to form an additional transverse row towards the adapical margin of each ambital plate. This new series never reaches the size of the true primaries, but reproduces all the morphological features of that series on a slightly smaller scale. The normal secondaries are numerous, very uneven in size, and form very regular scrobicular circles around the primary areolæ, though many scattered ones also occur. The miliaries are few, so that much of the surface of the plates towards the peristome is quite smooth.

The "raised secondaries" maintain their numbers over the whole surface, but are proportionately smaller than those of the adapical region. Their "areolæ" seem to be more noticeably elevated above the average plate level, but their mamelons are still minute and lacking in prominence. I have failed to find any "sunken tubercles" below the ambitus on the interambulacra, and, in view of the remarkable freedom from ornament of the plates near the peristome, I feel fairly confident in stating that they do not occur there.

(d) *The Ambulacra of the Adoral Surface.*

The most striking difference between the ambulacra and interambulacra of the adoral surface, in the matter of ornament, lies in the development of unusually numerous secondary tubercles and miliaries in the former areas. Both of these sets of structures are far from numerous on the adapical parts of the ambulacra, so that the adoral parts of these areas are distinguished from all the rest of the test-surface by their abundantly granular character. In scale this ornament is perhaps a little finer than that of the adjoining interambulacra.

The "raised secondaries" are present, though far from abundant, and are precisely similar to those on the adoral interambulacral plates. But, in contrast with the latter areas, "sunken tubercles" occur in addition. They are, however, very small, and seem to belong exclusively to the regular series of the adapical surface. They are restricted to the immediate neighbourhood of the "poriferous zones", and are placed with fair regularity on the perradiad side of every third peripodium. The plates on which they occur are, in the majority of cases, demi-plates. I have been unable to locate them with certainty on the plates at the ambitus, but these are so

small and so congested with granular ornament that their absence from that region is probably more apparent than real. Their general proportions and distribution are accurately shown in Pl. I, Fig. 3, of Geol. Mag., Dec. VI, Vol. I, 1914. It is noteworthy that the obliquity of their axes is exactly opposite to that of the adapical tubercles, the areolæ being inclined towards the ambitus in each case.

(e) *The Homology of the "Sunken Tubercles" of Discoides and the "Glassy Tubercles" of Echinoneus.*

The "sunken tubercles" of *D. cylindricus* are found over the whole coronal surface of the test except near the apex and on the interambulacra of the adoral surface. Their distribution on the plates seems to indicate that they are not fundamentally special structures but are modified examples of the secondary tubercles. As far as can be ascertained, the areolæ of the "sunken tubercles" are generally raised above the surrounding level on the side away from the ambitus, and are sunk more or less deeply below it on the opposite side. The greater part of each areola is depressed, and the sunken part is deeper than the raised part is high. Thus their mamelons, and whatever articulated projections that may have fitted on to them, are inclined towards the ambitus. These structures occur in *Plesiechinus*, *Pygaster*, *Holectypus*, and *Coenholectypus* as well as in *Discoides*, but, as far as my present observations have indicated, reach their maximum development, at least as regards numbers, in the last-named genus. They seem not to occur in *Conulus*. The material at present available for a study of *Pyrina* is inadequate, but I believe that they do occur in *P. desmoulinsi*, though in that species they seem to be wholly sunken, with an axis once more at right angles to the surface of the test. I have not seen any comparable structures in any other Mesozoic genera.

There are two sets of structures found in Tertiary and Recent forms with which comparison is possible. Many of the more specialized Spatangoids, such as *Lovenia* and *Eupatagus*, have a few large tubercles on the interambulacra of the adapical surface. These are set in very deeply sunken areolæ, and are usually oblique in relation to the test-surface. But two equally important features in the Spatangoid tubercles are in direct contrast with those of *Discoides* and its allies. The sunken tubercles of the recent forms are always primaries, in point of size, while those of *Discoides* are always smaller than the main tubercles; and the sunken character of the Spatangid areolæ seems to be due to the development of secondary thickening on the rest of the plates, and its absence from them, while the actual elevation of part of the areolæ in *Discoides* shows that such a growth has played no part in their production.

The other series of sunken tubercles with which comparison can be made is found in *Echinoneus* and *Micropetalon*. There can be little doubt that, from a phylogenetic standpoint, these genera are much more nearly related to the Holectypoida than are the true Spatangids, although it seems equally certain that they are not directly descended from *Discoides*. Scattered more or less promiscuously over the plates of both areas in *Echinoneus* are the small

depressed structures known as "glassy tubercles". Their structure and distribution are admirably figured by Westergren (Mem. Mus. Comp. Zool., Harvard, 1911). These glassy tubercles are roughly similar to the secondaries in size, but are distinguished from them by their deeply sunken areolæ and small "mamelons". Whatever the glassy tubercles may be, either in origin or function, their general facies is so extraordinarily like that of the "sunken tubercles" of *Discoides* that it is almost impossible to doubt the homology of the two structures. I have not noticed any specially vitreous appearance in the mamelons of the "sunken tubercles" of *Discoides*, but this might be due to fossilization or the imperfect development of the structures in Cretaceous times. If, as I believe, corresponding structures occur in *Pyrina*, which is very nearly allied to *Echinoneus* in all essential features, and almost certainly ancestral to it, the correlation of the two sets of ornament would be rendered more certain. Their absence from *Conulus* would indicate that that genus, though resembling *Pyrina* in many features, has diverged along a line of evolution leading to some other goal than *Echinoneus*, and one in which "glassy" or "sunken" tubercles are not developed. For the present it is enough to definitely state the opinion that the "sunken tubercles" of most Holectypoids are the forerunners of the glassy tubercles of *Echinoneus*.

3. The Spiniferous Pits of *Conulus albogalerus*, Leske.

(a) *Description of the Pits.*

This familiar and common species from the higher zones of the Upper Chalk may present very different surface features under varying conditions of preservation and preparation. Ordinarily the surface of the test is almost smooth on the adapical surface, owing to the faint relief and shallow areolæ of the primary tubercles, and the small size of the secondaries and miliaries. But most specimens that have been freed from their adherent matrix by gentle methods show, in contrast, a strongly shagreened character, which is caused by the projection of very numerous rounded prominences of considerable elevation but small diameter. These prominences are readily detached from the plates by too vigorous brushing, and seem to separate from them after a very slight degree of weathering; and they as often as not are removed with the matrix if this is broken off by a blow. That they commonly remain in position on tests which have been entirely denuded of radioles and pedicellariæ indicates that these prominences are not appendages of that type, but their frequent and easy separation from the plates with which they articulate proves that they are not tubercles. They seem to occur in almost the same numbers in *C. rhotomagensis* and *C. subrotundus* as in *C. albogalerus*, but owing to the toughness of the matrix in which the two former species are embedded, they are only exceptionally seen in situ.

The earliest description of the prominences scattered over the test of *C. albogalerus* is that given by Forbes (Mem. Geol. Surv., dec. III, pl. viii) in 1850, and no later accounts of them seem to add much to his statements and figures. The following are the sections of his

discussion of "*Galerites*" *albogalerus* which bear upon the subject. "The miliary tubercles of the dorsal plates bear very minute and short tubercular smooth spines, each standing apart from its neighbours. . . . [On the adoral surface] curious club-tipped pedicellaria-like bodies occur among [the normal radioles], which may represent the spines of the miliary tubercles described as occurring on the dorsal surface. . . . The minute moniliform spines of *G. albogalerus* are $\frac{1}{133}$ of an inch in length and of equal diameter. Three were measured, and all were as nearly as possible of the same size and proportions. They were all perfectly smooth." On pl. viii, fig. 8 are given two "greatly magnified figures of the small tubercular spines of the dorso-lateral plates". The spines figured are nipple-shaped, with smooth domes and splayed proximal margins. The description is incorrect in one particular, for these prominences do *not* occur on the miliary granules, nor yet on the secondary tubercles, but in association with small pits which are not indicated on Forbes' somewhat imaginative fig. 5. I am unable to confirm the presence of the "pedicellaria-like" structures on the adoral surface, but they may be attached by soft tissues only, and so only preserved when the ordinary radioles are in place. Otherwise, save for the correction made above, the description and figures seem thoroughly accurate, though by no means complete.

The study of such minute structures in a fossil is necessarily attended with great difficulty, and the observations made in one case need abundant and frequent comparison with separate investigations on numerous specimens. Fortunately, the prominences are so thickly scattered over the test, and examples of the species showing them in place are so common, that sufficient material for confirmatory analysis has been readily available. I have found that the most satisfactory process for a study of the surface details of *Conulus*, and indeed of most fossil irregular Echinoids, is to wash them over with Indian ink much diluted with water. This reagent leaves a very fine black deposit in all the small depressions of the test (such as plate-sutures and podial pores); and, if the surplus be rubbed off with a damp cloth before it has quite dried, only such depressions retain the stain. A brush must not be used for the removal of the ink, for it scours out the depressions irregularly, and produces disconcerting results. It must be borne in mind that a specimen so treated cannot be cleaned after the ink has once dried, so that valuable or borrowed specimens must be examined in their natural state.

Pl. XIII, Fig. 8, shows the general appearance of a series of coronal plates midway between the apical system and the ambitus in a specimen of *C. albogalerus* from the base of the *Uintacrinus* sub-zone of Shaw, near Newbury. All the projecting prominences have been removed by rubbing with a stiff brush, but none of the miliaries or tubercles have suffered in the process. The drawing shows all the external ornament of the plates, correct in position and proportions. To avoid perspective, the interambulacral plates have been projected up to the plane of the ambulacrum which they flank, the outlines having been traced from three separate photographs. It will be seen that there are four types of ornament. The main

tubercles, with broad bosses, crenulated parapets (omitted in the figure), and small mamelons, are set in areolæ which extend very little beyond them, and are arranged in an "hour-glass" plan on the interambulacral, and with some regularity on the ambulacral, plates. Abundantly scattered among these large tubercles, and roughly encircling them, are small secondaries, similarly set in areolæ, but without defined mamelons and imperforate. These vary slightly in size, but are remarkably uniform in character. Here and there simple granules appear, without areolæ; sometimes these are nearly as large and prominent as the secondaries, but usually they are very small. The fourth type is altogether different, and is somewhat diagrammatically shown in Fig. 8, but an enlarged view (Fig. 6) makes its characters clear. It consists of a series of pits of minute but very constant size, encircled by faintly raised and ill-defined smooth areas. These surrounding platforms are usually of about the same diameter as the areolæ of the secondary tubercles, but are rarely quite circular, and never so distinct as either of the figures suggests. Each of the structures might be compared to a shallow well with a broad but low parapet. The encircled pits are present in about the same numbers as are the secondary tubercles, and, like them, may enter into the scrobicular rings of the primaries, although the majority are scattered without apparent order. None of the coronal plates of the adapical surface, however small, is without them, and in the ambulacra they may be found near or even in contact with the peripodia. It is from these encircled pits that the small nipple-shaped "spines" project in unworn specimens.

One of the pits is shown, in plan and section, on Pl. XIII, Fig. 6. The pit is seen to be a roughly hemispherical concavity, comparable with the *negative* of a mamelon. The encircling platform may similarly be compared to a negative areola.

As far as can be ascertained, the encircled pits occur in varying numbers on all the coronal plates of the adapical surface of *C. albogalerus*. They are few and sparse on the young plates near the apical system, and increase in number (with no corresponding change in size) towards the ambitus, but I can find no trace of them on the adoral surface. The plates there are much more coarsely and closely granulate; and, if the structures under consideration do exist below the ambitus, they would seem to have become prominent instead of re-entrant. No pits occur on the plates of the apical system.

The "spines" which spring from the encircled pits are remarkably uniform in size and character over the whole adapical surface. Their appearance when viewed in situ is precisely like that of the figures given by Forbes (loc. cit., fig. 8). That author's remark that "they are all perfectly smooth" is, if anything, an understatement. The entire exposed surface of each "spine" is extraordinarily glossy, outshining even the primary mamelons in polish. When it is remembered that the radioles of this species have fluted, and even fringed, shafts, and crenulated collars, the contrast between them and the "spines" of the encircled pits is manifest. After many failures, I have succeeded in examining the articulating surface of the "spines", both in solid and sectional view. They show an

interesting, but not surprising, character. The greater part of the area of the "surface of attachment" is quite smooth and flat, and the whole surface is of considerably greater diameter than the top (or distal end) of the "spine" owing to the splaying out of the lower part of the "shaft". In the middle of the somewhat irregular circle of this surface there appears a roughly hemispherical knob, slightly but distinctly projecting beyond the general plane (see Pl. XIII, Fig. 7). This knob is almost exactly of the same diameter as a pit, into which it fits after the manner of the sutural knobs and sockets of *Arbacia*. The smooth part of the lower surface of the "spines" seems to correspond fairly accurately with the size and shape of the raised parapets (or "negative areolæ") around the pits. Such a mode of articulation would allow of very limited movement; indeed, the only opportunity would be for rotation of the "spine" about its long axis. There is no trace of muscular attachments, nor of perforation for a ligament, either on the plate or on the "spine", but the former, at least, may well have existed on the "negative areolæ" as they do on the normal ones. There is no indication of any syzygial union between the "spine" and its pit.

It seems, therefore, that an "encircled pit" represents a modified secondary tubercle, whose mamelon and boss have become re-entrant instead of projecting, supporting a glossy and short "spine" whose acetabulum is convex instead of concave, and whose collar is expanded to rest in contact with the raised areola. Whether the "spine" is merely the proximal part of some such appendage as a pedicellaria or not, cannot be determined. The surprising polish of its entire outer surface would imply that, if any prolongation of the structure existed, a region of soft, flexible tissue intervened between that and the distal end of the "spine".

(b) *Comparison with the Structures of D. cylindricus.*

The peculiar secondary tubercles of *Discoides* (referred to above) are the only structures with which comparison is possible. Nothing in the least like the "spiniferous pits" of *C. albogalerus* occurs, as far as I am aware, in any other Echinoid, fossil or recent, excepting the other species of the genus. In *C. subrotundus* and *C. rhotomagensis* they are present in similar numbers, and of the same character, as in the Upper Chalk species; so that they may be regarded as a generic, or possibly a family, peculiarity.

The specialized secondaries of *D. cylindricus* resemble the "pits" of *Conulus* in many important respects. They are definitely secondary tubercles in point of size and distribution, sharing with them in the construction of the scrobicular circles. They have areolæ which are usually raised above the surrounding level of the test, and which are never sunken like those of the normal tubercles (see Pl. XIII, Fig. 5). The mamelons are, it is true, convex, but they are unusually small, and are set in a deep excavation above whose rim they do not appreciably project. There is every reason to believe that these mamelons supported small "spines", but these would, owing to the exposed nature of their articulation, naturally become detached by the same processes that remove the normal

FIG. 1.

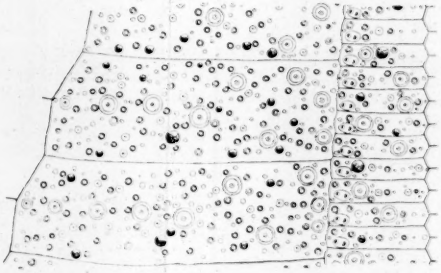


FIG. 2.

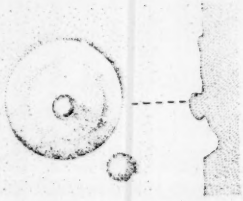


FIG. 3.

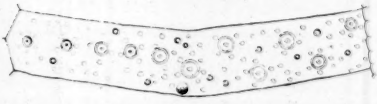


FIG. 4.

FIG. 5.

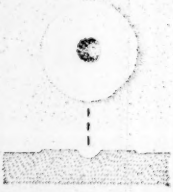


FIG. 6.

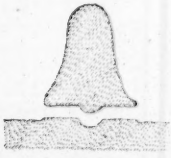
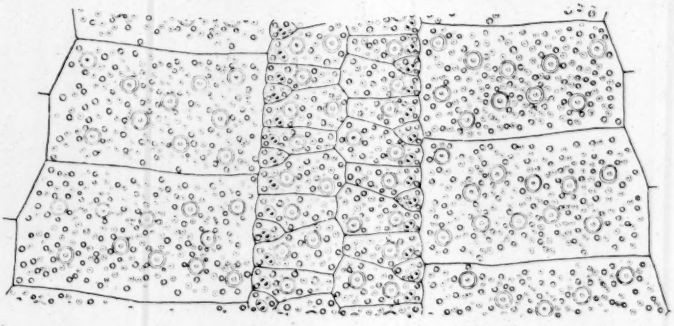


FIG. 7.



H. L. H. del. FIG. 8.

SURFACE FEATURES OF *DISCOIDES* AND *CONULUS*.

radioles. Thus the only serious difference that exists between these peculiar secondaries and the "pits" of *Conulus* is the presence of convex mamelons; but these are far less prominent than the normal ones of the same specimens. It may be fairly confidently suggested that the specialized secondaries of *Discoides* show an early stage in the evolution of the "pits" of *Conulus*, the areolæ having already risen, but the tubercles being only partly reduced. The apparent absence of the "sunken tubercles" of *Discoides* from the species of *Conulus*, and the almost certain absence of "encircled pits" from *Pyrina*, invite speculation as to the relationships of these three genera into which it would be premature to enter in this paper. It is sufficient for the present purpose to point out that, as regards these curious surface features, *Discoides* possesses both types, one of which occurs in *Pyrina* and the other in *Conulus*, two genera that are far in advance of *Discoides* on the path of true "Irregularity".

4. Summary.

Two sets of specialized tubercles are described, "sunken tubercles" and "negative secondaries". Both types occur in *Discoides cylindricus*, but the former type only is fully developed there. These "sunken tubercles" are believed to occur in *Pyrina* also, and are further correlated with the "glassy tubercles" of *Echinoneus*. They also occur in the earlier Holectypoida. The "negative secondaries" are found in their fullest specialization in *Conulus*, and there support the short, closely articulated, glossy "spines" that are familiar to all collectors who work in the Upper Chalk. There is thus an indication that there may be two distinct lines of descent from *Discoides* (omitting the obvious sequence to the Clypeastroids), in one of which the changes led to the recent *Echinoneus* through *Pyrina*, while in the other *Conulus* marks the first stage. No suggestion as to the physiological value of the two series of structures can be advanced.

EXPLANATION OF PLATE XIII.

Fig.		
1.	*Discoides cylindricus.*	Adapical portion of corona. × 5.
2.	,, ,,	Plates midway between apex and ambitus. × 5.
3.	,, ,,	A sunken tubercle in plan and section. × *c.* 30.
4.	*Holectypus depressus.*	Interambulacral plate midway between apex and ambitus (No. 17 from the ocular). × 5.
5.	*Discoides cylindricus.*	"Negative secondary" in plan and section. × *c.* 30.
6.	*Conulus albogalerus.*	"Encircled pit" in plan and section. × *c.* 30.
7.	,, ,,	Diagram of articulation of "spine" with pit. × *c.* 30.
8.	,, ,,	Plates midway between apex and ambitus (amb. III). × 5.

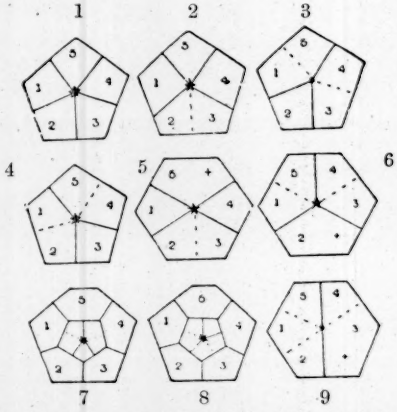
In figs. 1, 2, 4, and 8 the several types of plate-ornament are in their correct positions and proportions, but are represented by somewhat conventionalized patterns. The outlines of the figures are based on tracings from photographs as well as on actual measured drawings so as to ensure accuracy.

III.—The Base in the Camerate Monocyclic Crinoids.

By F. A. Bather, D.Sc., F.R.S., F.G.S.

(By permission of the Trustees of the British Museum.)

In "The North American Crinoidea Camerata", 1897, Wachsmuth & Springer discussed at length the various modes of partitioning the base, and attempted to give a morphological, if not a physiological, interpretation of the various appearances. In reviewing this part of their work (Geol. Mag., Sept. 1898, pp. 426–428) I contented myself with giving a summary of their views, corrected only in so far as facts of structure were concerned. This summary was reprinted in the Echinoderm volume of Lankester's *Treatise on Zoology* (1900, pp. 122, 123), although some of the theory involved in it was not in accord with the phylogenetic hypotheses expressed or implied in the taxonomic part of that work. Mr. Herrick E. Wilson[1] has been more critical. He has brought Wachsmuth & Springer's interpretations to the bar of logic, of fact, and of physiological theory, and has found it necessary to replace most of them by a fresh series.



Figs. 1–9.—Diagrams summarising the views of Wachsmuth & Springer on the structure of the Crinoid base. The posterior basal is numbered 5. The region where addition is supposed to have taken place is marked +.

Reference to Table A in Wachsmuth & Springer's monograph, or to Fig. 4 in my Review (here reproduced as Figs. 1 to 9), will show an area of the base marked *x* or + and believed by the American authors to represent the portion that was added to one or other basal so that it should fill out the space required. Mr. Wilson fails to understand what stimulus could have initiated this hypertrophy now in one place now in another; and, since the introduction of such a wedge involves torsion of the rest of the basal circlet, he seeks in vain for physiological processes that could bring this about or

[1] "Evolution of the basal plates in monocyclic Crinoidea Camerata": *Journ. Geol.*, xxiv, pp. 488–510; 534–53; 666–84, pls. i–iii. August to November, 1916.

processes of growth that could even permit it. Had Mr. Wilson not been in communication with Mr. Springer, I should have said that he had taken Wachsmuth & Springer's diagrams more seriously than those authors ever intended, and that his criticism was more laboured than the case demanded. At any rate he has swept the field clear, and his own conclusions may be discussed on their merits. They are:—

"1. The ancestor of the monocyclic Camerata was a simple, generalized crinoid with pentamerous symmetry."

If "generalized" means "Inadunate", then this supports the suggestion that I have more than once opposed to the views first of Wachsmuth & Springer and later of Professor Jaekel.

"2. The base of the pentagonal Camerata is not the result of reversion from an intermediate hexagonal stage, but is in a primitive condition as far as influence of the anal plate is concerned."

The sting in this seemingly obvious statement is the corollary that the quadripartite base of the Melocrinidae (Fig. 2) cannot be derived from that of such a form as *Xenocrinus* (Fig. 5). Such a derivation is one of the views above alluded to as inconsistent with my taxonomy. I have therefore no qualms in accepting Mr. Wilson's conclusion.

"3. The anal plate is of secondary origin, and originated by primary interpolation between the latero-distal margins of the posterior radials."

It is cheering to note Mr. Wilson's dismissal of the view that the anal *x* is a supplementary plate, suddenly introduced, and his clear exposition of its origin from some plate lying above the radials, which plate gradually grew downwards at its lower margin and became resorbed at its upper margin, without any disturbance of adjacent plates (see GEOL. MAG. 1899, pp. 40 & 44), and I welcome the extension of this theory to the Camerata.

"4. The hexagonal base of the monocyclic Camerata [our Figs. 5, 6 & 9] resulted from the separation of the posterior radials and trunkation of the posterior basal by the anal plate, the anal plate having been interpolated by portional migration in the space created by the demand of the hind-gut for enlargement."

This is a consequence of conclusion No. 3, and is a restatement of Beyrich's sentence (1871, p. 51): "Da das Hexagon nur dadurch entsteht, dass zwei Radien durch ein Interradialfeld bis zur Basis herab auseinandergeschoben werden. . . ."

"5. The widening of the posterior basal upon interpolation of the anal plate was bilaterally symmetrical."

This is not merely a statement of result, comparable to the conclusion of Beyrich's sentence: "so erhält das Hexagon für des Krinoid die Bedeutung eines symmetrischen Hexagons, u.s.w.," but it means that the posterior basal expanded equally on either side of the axis of symmetry, and not merely on its right side. In 1898 I pointed out that, as a statement of result even, this did not apply to all crinoids, but probably Mr. Wilson intends to refer only to Monocyclic Camerata. In them it can apply only to the hexagonal

quinquepartite base, as in *Tanaocrinus*, or quadripartite, as in Xenocrinidae (Figs. 1, 5). For such bases it is the most simple explanation; but, since the pressure of the hind-gut was presumably along the right posterior suture, one must admit the possibility of this having pushed the posterior basal over to the left and necessitated growth on its right side. This, as Mr. Wilson says (p. 669), is "a question of directive controls which cannot be readily answered". I prefer, therefore, to leave the door open.

> "6. The quadripartite, hexagonal base [our Fig. 5] resulted from the anchylosis of the anterior pair of basals in a hexagonal genus with a pentapartite base."

Translated into phylogeny, this means that Mr. Wilson follows Mr. Springer (1913) in accepting my derivation of Xenocrinidae from *Tanaocrinus* (1898, 1900).

> "7. The posteriorly directed basal suture in the subequally, tripartite and bipartite, hexagonal bases [our Figs. 1, 6 & 9] is the homologue of the right-posterior basal suture in the pentapartite and quadripartite bases, which has shifted its position through atrophy of the right half of the posterior basal and a compensating hypertrophy of the left side of the right-posterior basal."

The quadripartite base (hexagonal or pentagonal) always tends towards symmetry in itself and in relation to the sagittal axis (radial axis of Beyrich), so long as it remains quadripartite; but any fusion of its elements throws it out of symmetry with the sagittal axis, and to regain the relation a shifting of one or more sutures is required. Mr. Wilson argues that the fusion is of the posterior basal with the one on its left, and from this his conclusion 7 naturally flows. The evidence he adduces from an abnormal *Steganocrinus pentagonus* shows that the posterior basal could, on occasion, fuse with the one on its right. All the same his conclusion is to be accepted, not so much for the reasons he gives, as for the more general one that the right posterior suture is on the line of weakness or fluidity, due to intestinal pressure. The exception in the single *Steganocrinus* just mentioned was facilitated by its strongly marked radial pentamerism and by the relative smallness and solidarity of its base.

> "8. The basal sutures lost through anchylosis are potentially present in the basal cup, and liable to reappear in individual cases of delayed anchylosis, but not as a phylogenetic character."

That is to say, there is no reversal of evolution.

> "9. The tripartite, hexagonal base in the Batocrinidae resulted from the appearance of the posteriorly directed basal suture (see 7) in a quadripartite base, accompanied by closure of the anterior and left-posterior basal sutures."

This differs from Wachsmuth & Springer's interpretation (our Fig. 6) by the fusion of plate 3 with 2 instead of with plate 4; but it is not quite clear, for in a quadripartite base, on Mr. Wilson's own hypothesis, the anterior suture is the one already closed (as in our Fig. 5). All that happened was the fusion of the posterior and

left posterior basals (Nos. 5 and 1 in the figure) and the shifting of the right posterior suture as under 7. If this be Mr. Wilson's meaning, he is mistaken in thinking that I do not agree with it; but to his criticism of my supposed views I shall return later.

"10. The hexagonal, tripartite base of the Hexacrinidae resulted from the interpolation of an anal plate by portional migration, through shifting of the right-posterior basal suture to a posterior position, and closure of the anterior and left-posterior basal sutures, in a simple platycrinid with a pentapartite base."

"11. The bipartite, hexagonal base in the Hexacrinidae resulted from interpolation of the anal plate by portional migration, shifting of the right-posterior basal suture to a posterior position, and closure of the right-anterior basal suture, in a platycrinid with a pentagonal, unequally tripartite base."

["right-anterior" seems to be a misprint for "left-anterior".]

These two conclusions, apart and in conjunction, form the most novel part of Mr. Wilson's paper, and he has made out a fair if not absolutely convincing case. Wachsmuth & Springer thought that the tripartite *Hexacrinus* base (Fig. 6) was derived from a tripartite base of *Platycrinus* type (Fig. 3) by intercalation of the anal, swinging round of the right posterior suture to the sagittal axis, as in Batocrinidae, and widening of the left anterior basal (numbered 2). Mr. Wilson calls this a "torsion theory", and objects to an enlargement elsewhere than adjoining the right posterior suture; or, discussing an alternative hypothesis [where his meaning is perhaps obscured by another misprint] he says the theory "demands the reappearance" in Hexacrinidae "of the right-anterior basal suture" lost in Platycrinidae. Perhaps Mr. Wilson, here as elsewhere, does not attach enough importance to the general symmetry imposed by mechanical stresses, or to the selection-value of a stronger disposition of sutures. If, as he concedes, it was possible for the right posterior suture to shift 72° under certain stimuli, why should it be so impossible for the anterior suture to shift an equal amount under other stimuli? Mr. Wilson, however, prefers to derive his Hexacrinid base from the quinquepartite base of a primitive Platycrinid (Fig. 1), and to imagine it as composed of posterior (5) and left posterior (1) basals fused, left (2) and right anterior (3) fused, and right posterior (4) enlarged. He is entitled to his hypothesis, but it is still open to the objection which I raised in 1900, that no Silurian form is known which could link the imaginary 5-basalled Platycrinid with the Devonian Hexacrinid.

The bipartite base of *Dichocrinus* and other Hexacrinidae (Fig. 9) was regarded by Wachsmuth & Springer as derived from the tripartite Hexacrinid base (Fig. 6) by the fusion of the compound plate on the left (5 + 1) with the small (left anterior) basal (2), and by the shifting of the anterior suture back again into the sagittal plane. This seemed plain sailing, but Mr. Wilson again objects that "the pressure from the growing hind-gut . . . cannot affect the anterior basal sutures". Granted; but, as before, why overlook the mechanical stimuli? "Furthermore, the examples of [abnormal]

suture reappearance in the bipartite base show the potential presence and position of all but the right-posterior suture." One of these examples (Wilson's plate vii, fig. 10) shows left posterior, anterior, and right anterior sutures, which last does not accord with the enlargement of the right anterior basal (3 +) imagined by Wachsmuth & Springer. The two other examples show a suture in the anal interradius, and why the hypothesis demands that this should have been shifted back to the right posterior radius I do not understand. Mr. Wilson also objects, as before, that the anterior basal suture "lost through anchylosis" cannot reappear. But it is only Mr. Wilson who has supposed that suture to be lost; Wachsmuth & Springer thought it was shifted; and to claim that it could not shift back is to ride "the irreversibility of evolution" a little too hard. Perhaps Mr. Wilson is bothered by Wachsmuth & Springer's added element *x*, but, as already said, I think he attaches too much importance to a diagrammatic mode of expression. However, let us look at his own interpretation (having first corrected another unfortunate misprint). He derives the *Dichocrinus* base (Fig. 9) from one of Platycrinid plan (Fig. 2), by fusion of the left compound basal (5 + 1) with the small (left anterior) basal (2), accompanied by a shifting of the right posterior suture into the anal interradius, in line with the unmoved anterior suture. Granted the antecedent conditions, this is certainly a simpler explanation, though Mr. Wilson does not say how he reconciles it with his own views as to the right posterior suture in abnormal individuals. In choosing between the two interpretations we must be guided by the phylogeny, and here Mr. Wilson claims that the earlier examples of *Dichocrinus* have a flexible tegmen more readily to be derived from that of an early Platycrinid than from the "ridged tegmen" [?"rigid"] of *Hexacrinus*. This seems a fair argument, and in this case plenty of Silurian and Devonian genera are known that could be thus linked up with *Dichocrinus*. If Mr. Wilson's interpretation of *Dichocrinus* be accepted, then, whatever be the interpretation of *Hexacrinus*, it will follow that the two genera evolved along independent lines.

Such are the main theses of this interesting paper; but there are subsidiary matters that call for comment.

In saying that Wachsmuth & Springer are the only writers who have undertaken a general treatment of the subject, Mr. Wilson is hardly fair to H. E. Beyrich, whose well-known paper "Ueber die Basis der Crinoidea brachiata"[1] finds no place in his "Bibliography". If Mr. Wilson has not studied that paper he has not been fair to himself either. Allusion has already been made to some of its broader conceptions, here overlooked; and, to descend to a detail, Mr. Wilson would have learned from it that the plan of base which he has discovered in some specimens of *Melocrinus* from Missouri, was described by Beyrich as normal for *M. hieroglyphicus*.

In his account of plate-growth (pp. 501, 502) Mr. Wilson suddenly breaks away from sentences with a strangely familiar ring to state that the plates, after they have come into contact, increase in size

[1] *Monatsber. Akad. Wiss. Berlin*, February, 1871, pp. 33–55.

"by interstitial growth" (p. 502, also p. 497). The phrase is taken from Wyville Thomson's account of the development of *Antedon* (1865). Whether Wyville Thomson used the phrase (which he qualified by "apparently") in its customary meaning or no, there is no support for the idea. It might, if true, have been useful in explaining the changes in the basal plates, but Mr. Wilson makes no further use of it.

Mr. Wilson is strongly disinclined to believe that division of plates has ever occurred as a process of normal development in Echinoderms. Indeed, he stoutly affirms "that there are no known instances of the bisection of a growing plate in modern Echinodermata" (p. 674). This is a question of deep morphological importance. Presumably Mr. Wilson has not made his assertion without ransacking the literature; and yet one would like to hear what the embryologists have to say.

In discussing possible methods of plate migration, Mr. Wilson says (p. 539, I quote from a copy corrected by him): "in *Antedon* . . *Promac*[h]*ocrinus* and *Hathrometra* . . . the anal and radianal, being more firmly attached to the viscera than to the adjacent plates, are bodily lifted out of the cup into the tegmen by the accelerated growth of the hind-gut. This process is the one which undoubtedly explains the migration of the radianal in all fossil crinoids." This explanation may perhaps be correct for the recent crinoids mentioned, and it may perhaps apply to the later evolutionary stages in the Dendrocrinoidea (Poteriocrinidae *s. lat.*); but to say that it is "the one" explanation for "all fossil crinoids" overshoots the mark. In the first place the observed ontogeny of the comatulids cited is too rashly applied to the supposed phylogeny of various extinct genera in which there is no actual proof of migration during individual growth. After all, the view has been held that the ontogenetic changes in the comatulids are a recapitulation of previous phylogenesis (Bather, 1893, Recapitulation Theory in Palæontology. *Nat. Science*, II, p. 275, also III, p. 238). The plates of the cup are not really "attached to the viscera", but lie in the integument. It is true that in the larval *Antedon* the anal is not closely apposed to the adjacent cup-plates; but in palaeozoic crinoids there was a well-formed sutural union. The growth of the hind-gut was no doubt the stimulus, but its action can hardly have been a direct pull. The anal area first widened to give it room, and the space was filled partly by a *downward* growth of some plate above, partly by widening of the adjacent radials and the posterior basal, partly by portional migration (to adopt Mr. Wilson's useful phrase) of that plate below the right posterior radial which we call the radianal, sometimes even by development of a supplementary plate below the radianal (e.g. *Carabocrinus*). In these cases the expansion of the radianal was in an adanal direction, but usually along a horizontal line, sometimes even downwards into the basal circlet (e.g. *Carabocrinus*, *Strophocrinus*, and *Thenarocrinus*, all overlooked by Mr. Wilson); it was no more dragged up than was the upper anal dragged down. Sometimes the widening of the cup was effected in a different manner; in the Pisocrinidae and Catillocrinidae, for instance, the radianal has enlarged on the right side of the right

posterior radial—it has grown away from the anal interradius. To this Mr. Wilson's explanation cannot apply. I entirely agree with his emphasis on the pressure exerted by the hind-gut (p. 545); but while I admit "push" and "shove", I reject "lift" and "pull".

In discussing the evolution of the Batocrinoidea (p. 671) Mr. Wilson seems to have misunderstood some remarks in the Echinoderm volume of Lankester's "Zoology" (1900, pp. 165, 166), since he writes "Bather, in accepting this theory [Wachsmuth & Springer's derivation of the tripartite hexagonal base from one of Platycrinid plan] apparently assumes an intermediate step, for in the generic discussion of *Abacocrinus* he says: 'From the imagined intermediate step (not from *Abacocrinus* itself) *Periechocrinus* may have been derived by fusion of 2 BB.'" The quotation is inaccurate, and the interpretation of it wrong. A few lines back I had written: "Between it [the Silurian *Abacocr.*] and [the Ordovician] *Compsocrinus* we must imagine a form in which the free Br became biserial, while the free rami forked several times"; and I continued: "From the imagined intermediate form . . . *Periechocrinus* may have been derived by fusion of 2 BB." The intermediate form of course resembled *Compsocrinus* and *Abacocrinus* in having 4 basals, with the posterior basal truncate and supporting an anal. Also, since *Periechocrinus* has 3 basals, if these were derived "by fusion of 2 BB", its ancestor must have had 4 basals. Therefore I neither "accepted" nor "emended" the theory of Wachsmuth & Springer, but my working hypothesis was the one which Mr. Wilson has himself supported with such wealth of argument.

It is delightful to find a new worker ready not only to ask a heap of inconvenient questions, but to work out the answers to them. I trust that this article has done justice to his suggestive paper. But whether the fault be the author's, or his printer's, or his reviewer's, it is to be feared that the attempt at elucidation has led me yet again into what a good-natured critic once described as my unforgiveable "habit of offering up his own interpretations of what he does not thoroughly understand in the works of other authors". If the account does not tally with Mr. Wilson's intentions, I hope he will forgive me all the same.

IV.—*Poikilosakos*, a remarkable New Genus of Brachiopods from the Upper Coal-measures of Texas.

By D. M. S. Watson, M.Sc., Lecturer in Vertebrate Palæontology, University College, University of London.

(PLATE XIV.)

INCLUDED in a large series of marine fossils which I collected from the Cisco Beds of Uralian or Upper Coal-measure age at a well-known locality on the west bank of the Salt Creek at Graham, Young Co., Texas, are several fragments of a single very large nautiloid shell. These fragments had lain so long on the sea-floor before they were covered by mud that they have in many cases been much eaten into by sponges and worms, and are covered by adherent organisms, mostly Bryozoa. Attached to them, however, are twenty

specimens of the remarkable Brachiopod which forms the subject of this paper. These specimens are in general perfectly preserved, and are easily freed from their surrounding clay by washing with a tooth-brush.

All the specimens preserved are ventral valves. Each is adherent by the whole of its external surface usually to the outer, but sometimes to the visceral surface of the nautilus shell, or even to an adherent Stromatoporoid. Where an individual has been fixed on a flat surface and has had so much free space round it that it could grow freely, it forms an almost circular area whose margins are exceedingly thin and tightly adherent to the base. On rough surfaces and where two individuals have met and interfered with one another the general form may be very irregular. The largest individual I have measures 2·4 × 1·7 cm., the smallest ·75 × ·65 cm.

The hinge-line is straight and very short, in adults one-sixth the width of the shell. It is a very distinct groove whose posterior side is formed by a ridge standing up from the shell. The posterior surface of this ridge falls rapidly to an expansion of the valve which is usually of small extent, and in the smallest individual is nearly absent. The posterior surface of this ridge is the area, so reduced as to be almost unrecognizable. The delthyrium is represented by an extremely shallow notch in the middle of the hinge-ridge, which is invariably present though difficult to see. There is no trace of a deltidium either true or false.

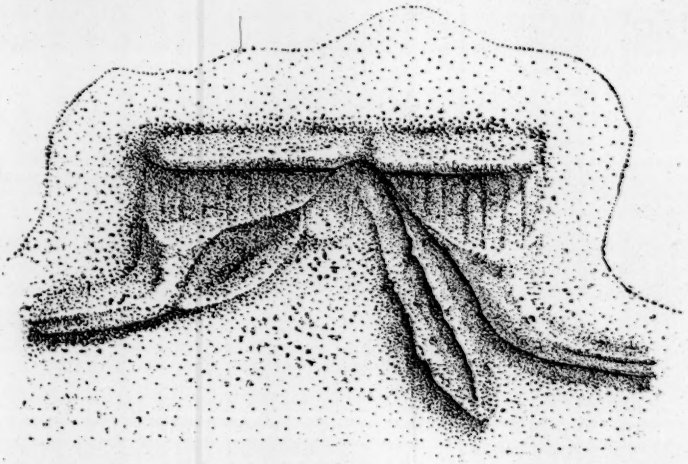
On the anterior side of the hinge-line and at its outer ends are two triangular thickenings separated from one another by the posterior end of the cavity of the valve. These thickenings presumably represent the teeth, although as they do not project at all and cannot have been interlocked with anything in the dorsal valve it may be more accurate to regard them as the remains of dental plates. I shall refer to them as the dental areas. Each dental area is shallowly concave antero-posteriorly and in young examples is obscurely striated, the striæ running parallel to the median plane of the shell. At its antero-lateral corner each dental area passes directly into a thickening of the shell which runs round to meet the other in the middle line anteriorly. This thickening, which forms a very definite flange rising from the generally flat visceral surface of the valve, is thrown into loops, symmetrically disposed and pointing towards the cardinal region. In the youngest individual the only well-marked loop is axial in position, passing from the anterior margin more than half-way to the hinge-line. In older specimens this axial loop becomes much enlarged and may reach three-quarters of the distance from the anterior margin to the beak. In all the specimens except the youngest there are in addition two main pairs of loops symmetrically placed; of these the posterior is the larger. Finally there are other smaller emarginations which in still more aged individuals might be supposed to become loops. In certain specimens the outer parts of the loops may become confluent, forming a single ridge.

The flange is always highest at the inner end of a loop and shallower peripherally. The flange is sharp-margined, and, except in the loops, excavated on the inner side just below its edge so as to

form a distinct ledge or rabbet. Outside the flange the shell is continued by a thin featureless adherent film to the irregular margin.

The muscle-markings are restricted to the posterior end, in fact lie largely between the dental areas. In full-grown individuals the inner margin of the dental area of the left side (spectator's left when the shell is placed with the hinge-line uppermost) is slightly excavated for an abductor muscle, whose insertion is on a narrow area on the side of the dental area, not reaching to the umbonal region, and in two individuals clearly limited to a small raised area with a distinct admedian margin.

In most specimens there is no distinct area for the insertion of an adductor on the left side, but in one or two where the shape of the surface on which the shell grew has led to the existence of a small hollow below the hinge-line and between the dental areas, this muscle is represented by a small well-marked depression, separate from the abductor insertion.



Schematic figure of the posterior region of the ventral valve of *Poikilosakos petaloides*. × 8. In this figure all the morphological facts to be seen in the whole series of specimens are introduced.

The adductor on the right side has a large and very well-marked insertion which occupies a long narrow area passing forward from the umbo nearly parallel to the inner edge of the dental area for a considerable distance, sometimes a quarter of the shell length. This muscle insertion is raised anteriorly on a special thickening of the shell, the edges of which grow up round the muscle so that the insertion lies at the bottom of a groove which may be of considerable depth. The walls of this groove are so placed as to show that the muscle passed obliquely across to the dorsal shell and was attached to it either on the middle line or beyond it on the left side. There is no evidence of the existence of an abductor muscle on the right side, as there is no such excavation of the dental area as forms its insertion on the left side, and the outer wall of the thickening for the insertion

of the right adductor is often in close contact with the dental area in the region where the implacement should be.

The visceral surface of the shell is usually smooth, but in certain individuals has a pustulose surface exactly resembling that which is usually found on the visceral surface of the shells of *Strophalosia*. The shell shows no signs of being punctate, and apparently consists of a single layer. Apart from the ridges it is extremely thin, perhaps seldom exceeding ·1 mm.

The preceding description contains a purely objective statement of the facts shown in my specimens of this Brachiopod. From them it is possible to draw certain conclusions as to the structure of the dorsal valve and the animal's structure and habits.

It seems certain from the whole structure that the dorsal valve covered only the space included within the raised flange and that, when closed, its edge rested in the rabbet on the inner face of that rim; the margins of the shell would thus be uncovered all round, as they must certainly have been in the region posterior to the hinge-line. This disposition of the dorsal valve shows that the flange is really the edge of the ventral shell, the areas lying outside it being merely of the nature of callosities developed for more perfect fixation.

The fact that only a single asymmetrical abductor muscle can be recognized suggests that the two valves could not be opened widely, if at all, by a strict hinge action at the hinge-line, and the equally marked disparity between the adductors can only be explained by supposing that the action of the two kinds of muscles together was to slew the dorsal valve round on the ventral so as to bring the slits in the dorsal valve, which correspond to the loops of the flange of the ventral valve, over the areas between the loops, thus allowing a free circulation of water.

The differences between the very small and the large specimens show that the loops originally develop as notches on the edge of the dorsal valve by a failure to grow at certain spots on the edge of the mantle. The whole structure is, in fact, developed by an emargination of the edges of the shell similar to that which divides the valves of Bilobites or *Pygope* into such distinct halves.

From the very small unbroken area which remains inside the shell it seems certain that the lophophore could not have been spirally coiled as it is in most Brachiopods, but must have been persistently larval as it is in the Thecideidæ and *Argiope*, passing in front of the mouth and forming a decollated band following the edge of the dorsal valve.

For this Brachiopod I propose the name *Poikilosakos petaloides*, gen. et sp. nov. The original of Pl. XIV, Fig. 1, is the holotype.

Poikilosakos at once recalls *Keyserlingina* from the Uralian beds of Russia. From Tschernyschev's description of casts of the visceral surface of the ventral valve, which alone are known, it is obvious that the two forms resemble one another in having a large ventral valve, and a much smaller dorsal one whose edge is dissected and fits into a raised ridge on the ventral valve, which is thrown into quite similar loops in the two genera.

The text-figure given by Tschernyschev of the real appearance of

the interior of the ventral valve as determined from the casts seems to me to be unworkable, and I prefer to leave any further comparison to those who are able to re-examine the specimens. There is no question of generic identity, as in *Keyserlingina* the ventral valve is strongly convex and probably not completely attached.

A far more interesting comparison is with *Leptodus* (= *Lyttonia*). Except that it is only attached by the umbonal region the young specimen of *L. americanus* figured by Girty, 1908, pl. iv, fig. 8, agrees extremely closely in its outline with our specimens, having an axial slit in the dorsal valve, and on the right side at any rate, when viewed from the dorsal surface, two lateral incisions. This specimen also shows a short straight hinge-line in the form of a groove, and distinct dental areas quite similar to those of *Poikilosakos*, so far as they are not concealed by the dorsal valve.

As Girty has pointed out, in his species the lateral "septa" of the ventral valve very often take the form of long, narrow loops, which, as shown in his pl. xxv, figs. 2 and 1*a*, are very like those of *Poikilosakos*. In *L. americana* the medium septum in the ventral valve bifurcates towards the anterior end, and the dorsal valve is always split by a medial incision from the anterior margin.

The figures of *Lyttonia nobilis* given by Waagen, pl. xxx, figs. 6 and 9, show that the muscular impressions on the ventral valve of shells of this genus agree with those of our new genus in being long and narrow in shape, very small in size, restricted to the extreme posterior end of the shell, and widely separated from one another anteriorly. These figures also suggest that there is some difference in size of the muscles of the two sides, though such disparity does not approach the remarkable condition seen in *Poikilosakos*.

These resemblances leave no doubt that *Poikilosakos* is a member of the Lyttoniidæ and that it is an early and primitive member of this group. Taken in connexion with *L. americanum* the comparison makes it certain that, as Girty has already suggested, the "septa" of *Lyttonia* both lateral and median are no true septa, but have arisen by the growing together of the edges of a deep slit in what is the functional and morphological, though not the real edge of the valve, a process which in exceptional regions of certain specimens of *Poikilosakos* has already taken place. This origin affords a simple explanation of the fact which Noetling has recorded, that the "septa" of the ventral valve of *Oldhamina* are double in structure. The fact that the remarkable pinnate dorsal valve of *Oldhamina* has developed by the excessive emargination of the shell, when considered in connexion with the probability that in *Poikilosakos* the lophophore was a continuous band following the margin of the dorsal valve which supports it, allows us to deduce a hypothetical structure and a theory of the functional arrangements of this remarkable type.

It is probable that in *Oldhamina* each pinna of the dorsal valve supported a double band of lophophore running its entire length, and that the median septum was provided with a strip of lophophore on either side. Noetling showed that each pinna of the dorsal valve rests its anterior edge on a "septum" of the ventral valve, so that the cavity of the shell forms a series of canals leading to a pair of

central channels running antero-posteriorly. Each of the lateral canals is open to the outside by a slit running the entire length of the dorsal pinna, formed by the gap between that pinna and the one behind it. If we suppose that the ciliary currents are driven down these lateral canals and by the action of the strip of lophophore along the side of the median septum are urged towards the posterior end, we have a feeding arrangement which, though not exactly paralleled by anything we know, should have been as efficacious as we infer from the immense size of *Lyttonia* it must have been.

Since the time of Waagen it has been customary to refer *Oldhamina* and *Lyttonia* to a special sub-family Lyttoniinæ of the family Thecideidæ. This view has been accepted by subsequent authors, although only with great reserve by Noetling. The much less specialized *Poikilosakos* affords better material for comparison with *Thecideas* than the later *Oldhamina*. *Poikilosakos* and the true Thecideidæ have in common only the attachment of the ventral valve and the lobed lophophore.

The attachment of the ventral valve is not a feature of great systematic importance, as it has repeatedly arisen in Brachiopods. The lobed lophophore if strictly comparable in the two groups would be of much greater importance, but the early Lyttoniids, both *Poikilosakos* and *Keyserlingina*, show that the lobing of the lophophore in that group has developed in consequence of a notching of the edge of the dorsal valve, whilst the early true Thecideas, of which the first large series are of Upper Liassic age, show no trace of any incision of the margin of the dorsal valve, but suggest that the lobing of the lophophore has arisen in them through the upgrowth in the dorsal valve of true septa quite analogous with the median septum which in the life-history of all Terebratellidæ and Dallinæ notches the anterior margin of the primitively circular brachideal band.

There is thus no evidence at all that the Lyttoniidæ and the Thecideidæ are allied. The two groups differ markedly in the very early and complete loss of an area and delthyrium in the former and its retention in a typical form by the latter group, and in the great reduction of the muscles together with a probable loss of power of opening the shell in the earlier family contrasted with a highly developed musculature and a power of opening the shells at right angles in the Thecideidæ. It is thus necessary to place the two groups in independent families and to discuss their relationships separately.

The interesting Brachiopod *Pterophloios emmerichi* from the Kössen Beds deserves to be considered in the light of this distinction between the Thecideidæ and Lyttoniidæ. I know it only from a single dorsal valve in the British Museum, and from Zugmayer's figures. In shape it resembles a small *Oldhamina*, having strongly involute valves and being attached only by a small portion of the umbonal region. It has neither area nor deltidium. The "septa" which occur in both valves split at their outer ends and form a continuous band following the margin of the shell, and much more resemble the septa of the ventral valve of *Oldhamina* than of any true Thecidia. It differs from every known Lyttoniid in having a solid

dorsal valve with a continuous margin. There is, however, no difficulty in supposing that the entire margin has secondarily developed by a fusion of the edges of the pinnæ of *Oldhamina* analogous to that which we have supposed to have formed the "septa" of the ventral valve of that form. I am therefore disposed to refer *Pterophloios* to the Lyttoniidæ, a family whose definition will then become:—

Family Lyttoniidæ.—Protremata cemented to a foreign object either throughout life or in youth by a ventral valve with area, delthyrium, and teeth vestigial or absent, with a flange on which the edge of the dorsal valve fits. Dorsal valve smaller than ventral and with a deeply slit margin, there being a single anterior median and paired lateral slits. The slits in the dorsal valve and the folds in the flange of the ventral valve which correspond to them may close up so as to form false septa, and produce secondarily an entire margin to the dorsal valve. The muscular insertions on the ventral valve are long, narrow, rather widely separated anteriorly, and may be very unsymmetrically developed.

Genus *Poikilosakos*, gen. nov.—Lyttoniids with the ventral valve cemented throughout life by its whole area. Only two pairs of lateral slits in the dorsal valve. Muscles asymmetrically developed, the abductor of one side and the adductor of the other alone being functional. Type, *Poikilosakos petaloides*, sp. nov. Cisco Beds (Uralian): Graham, Texas.

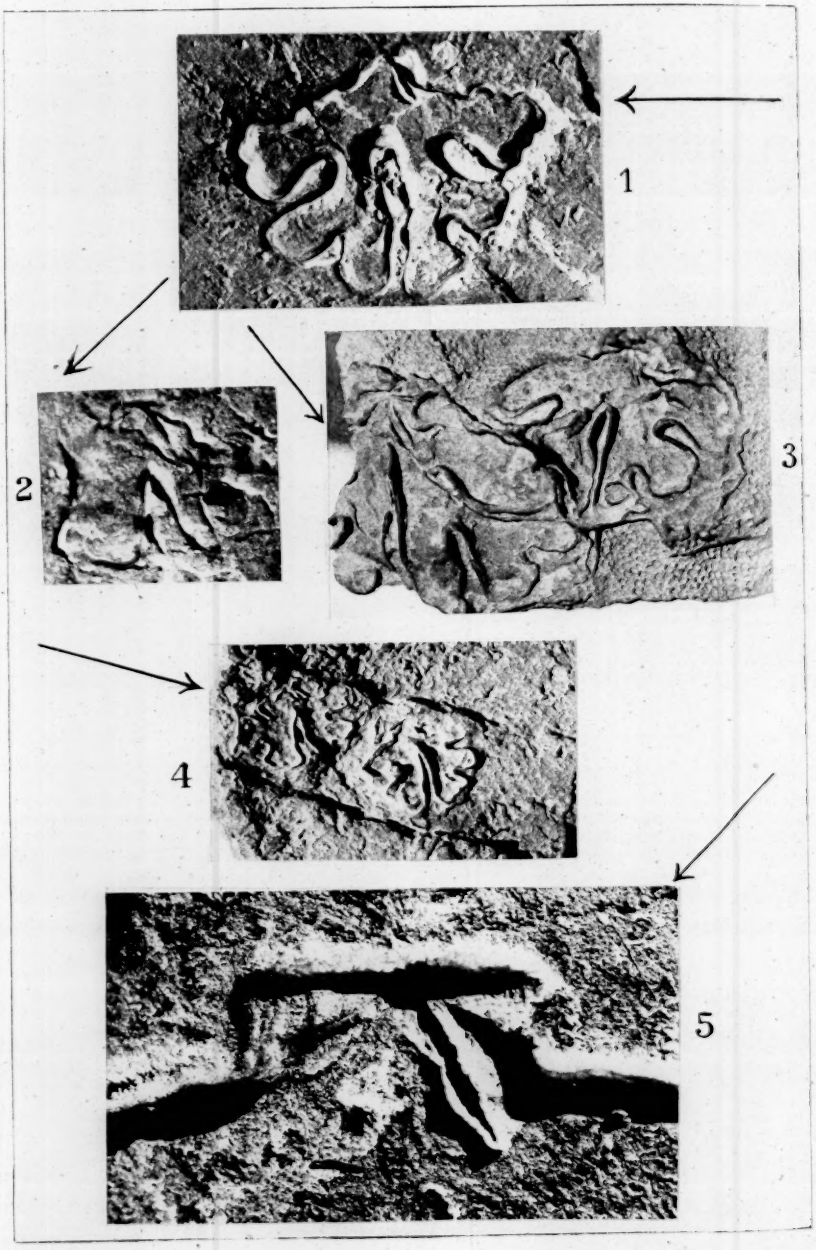
Keyserlingina, Tschernyschev.—Lyttoniid with the ventral valve strongly convex, cemented only by part of its area. Only two pairs of lateral slits in the dorsal valve. Type. K. Uralian: Timan, Russia, and the Carnic Alps.

Lyttonia, Waagen (=*Leptodus*, Richthofen).—Lyttoniids with very large, narrow, flat ventral valve, cemented only by the umbonal region. From ten to twenty-five pairs of lateral slits in the dorsal valve in adults. Folds in flange of ventral valve fused to form "septa". Muscles nearly symmetrical. Artinskian and later: Salt Range, India; Lo-ping, China; Guadaloup Mountains, Texas; Sosiokalk, Sicily; ? Timor.

Oldhamina, Waagen.—Lyttoniids with large, very convex, involute ventral valves, attached by the umbonal region in youth, subsequently becoming free and developing a callus over the posterior end. Very many pairs of lateral slits in the dorsal valve. Folds in flange of ventral valve fused to form septa. Post-Artinskian: Salt Range, India.

Pterophloios, Gümbel.—Small Lyttoniids with a convex ventral valve cemented only in youth by the umbo. About seven pairs of lateral slits in the dorsal valve. Edges of slits in the dorsal and folds in the flange of ventral valve fused so as to form septa, and restore an entire margin to dorsal valve. *Pterophloios emmerichi*, Gümbel. Rhætic: Kössen, Austria.

Beyond the fact that they were undoubtedly members of the Protremata, it is impossible to gain any idea of the ancestors of the Lyttoniidæ. It is natural to suppose that their ancestors retained an



F. Pittock, Phot.

POIKILOSAKOS PETALOIDES, *gen. and sp. nov.*

embryonic type of lophophore and had not developed the spirally coiled brachidium which we know to have occurred in many Strophomenids and Productids. When, however, a stage is retained in the life-history it seems not impossible that descendants of an animal which has passed that stage in its adult structure may nevertheless stop at such a stage, and hence be more primitive in their structure than their own immediate ancestors. It is therefore not impossible that the Lyttoniidæ have been derived from some Strophomenid, as in that group we get the closest parallel to the curious long narrow muscular insertions in the ventral valve.

I wish to express my thanks to the Trustees of the Percy Sladen Fund for the opportunity of visiting Texas and collecting the material on which this paper is based.

LITERATURE REFERRED TO.

GIRTY, G. H. 1908. "The Guadalupian Fauna": U.S. Geol. Surv., Professional Paper 58.

ZUGMAYER, H. 1850. "Untersuchungen über Rhätische Brachiopoden": Beitrage zur Pal. Ost.-Ungs. m. d. Orient., Bd. i, p. 19.

WAAGEN, W. 1883. "*Productus* Limestone Fossils": Pal. Ind., ser. XIII.

NOETLING, F. 1905. "Untersuchungen über die Familie Lyttoniidæ": Waag. emend. Noetling, Palæontogr., Bd. li, pp. 129–53, pls.

TSCHERNYSCHEV, T. 1902. "Die Obercarbonischen Brachiopoden des Ural und des Timan": Mém. du Comité géologique, St. Petersburg, vol. xvi, pp. 433–749, pls. 63.

EXPLANATION OF PLATE XIV.

Photographs of specimens of ventral valves of *Poikilosakos petaloides*, gen. et sp. nov., from the Cisco Beds, Upper Coal-measures, Graham, Young Co., Texas.

FIG. I. A large symmetrically developed specimen to be regarded as the holotype. × 2 approx.

II. A very small specimen. × 4 approx.

III. Two large irregular specimens, the left of interest because the edges of the right posterior lateral loop have grown together to form a false septum. × 2 approx.

IV. Two individuals of medium size. × 1.

V. The posterior part of a large shell. × 8 approx.

REVIEWS.

I.—A DESCRIPTIVE CATALOGUE OF THE METEORITES COMPRISED IN THE COLLECTION OF THE GEOLOGICAL SURVEY OF INDIA, CALCUTTA (on August 1, 1914). By J. COGGIN BROWN. Mem. Geol. Surv. India, vol. xliii, pt. ii, pp. 149–287, 1916.

THE collection of meteorites in the Calcutta Museum originated with the purchase, in 1865, from R. P. Greg (in this catalogue wrongly designated Professor) of his collection of meteorites. This collection must, of course, not be confused with the large collection of minerals, including meteorites, which belonged to his father, R. H. Greg, and was purchased by the Trustees of the British Museum in 1860. In 1868 the Calcutta collection was further

enriched by the absorption of the specimens belonging to the Asiatic Society of Bengal, and at the date the catalogue was written included specimens representing 379 falls and finds.

The arrangement of the catalogue is alphabetical according to the name of the meteorite, and particular care has been taken to secure accuracy in the names of India meteorites. Under each entry we find the date of the fall or find, the locality, a description of the specimen, its registered number, and the weight. Brezina's classification is used.

A small piece of criticism that suggests itself is whether it is wise to issue a catalogue of this character among the memoirs of the Survey and not as a separate publication.

II.—Handbook and Descriptive Catalogue of the Meteorite Collections in the United States National Museum. By George P. Merrill. pp. x + 208, with 41 plates. Washington: Government Printing Office. 1916.

THIS excellent publication, which constitutes Bulletin No. 94 of the United States National Museum, comes from the pen of the well-known Head Curator of Geology in that Institution. In the preface he tells us that, while the book is intended primarily for the use of the general public, it is so arranged as to meet the requirements of the student and the investigator. The great difficulty that confronts the writer of a work of this kind is how much knowledge may be presumed of the average visitor to the museum, and therefore how much to say and how much to leave out; sometimes the attempt to keep the phraseology free from technicality results in the information given being at the best misleading and at the worst wrong. Mr. Merrill for his part has not hesitated to take the reader into comparatively deep waters, but the plunge should prove stimulating to anyone of at least average education. The frequent quotation of the results of chemical analyses may possibly have a forbidding appearance to readers unacquainted with their meaning.

The book is divided into two parts, of which the first, running to 28 pages, is really a compendious textbook on meteorites. A brief explanation is given of Brezina's cumbersome classification, which *faute de mieux* is retained in the book, and the constituent minerals of meteorites are described. A few pages are devoted to the structure of meteorites, particular attention being paid to the curious chondrules characteristic of many stones. The exact process by which these granular masses have been formed is still a little uncertain; in one peculiar type of stone—the Allegan—glassy chondrules are found in a crystalline matrix, which is contrary to what would have been expected. Mr. Merrill discusses on the usual lines the early records of meteorites, and the phenomena accompanying the fall. He, however, omits to say anything about their possible origin, or the light that the study of the solidification of alloys has thrown on the structure of the siderites and the metallic portion of aerolites.

The second part of the book consists of the catalogue of the collection of meteorites in the United States Museum. At the date of publication it contained specimens representing 329 falls and finds, but in addition it has been enriched by Dr. C. U. Shepard's bequest, after his death in 1915, of the meteorite collection brought together by his father, the late Professor C. U. Shepard, one of the earliest American mineralogists. The latter collection had been deposited in the Museum on loan for some years; it comprises 234 falls and finds, of which 83 were not represented in the general collection. The total number of falls and finds therefore represented in the Museum is 412. The present catalogue succeeds two others, the one written by Dr. F. W. Clarke in 1889 and the other by Mr. Wirt Tassin in 1902. Since they were compiled the entire collection has been re-arranged independent of the mineral collection, of which it had formerly been considered a part, and is now treated as belonging more properly to petrology. The arrangement of the catalogue is alphabetical under the names of the falls and finds, the names being nearly always derived from the locality. Under each entry are given the group in the system of classification to which the meteorite may be assigned, a description of the specimen in the collection, particulars of the fall, and other details, if known, such as the chemical composition, and at the close a reference to the literature from which the abstract has been compiled. For fuller information the reader is referred to Wülfing's *Die Meteoriten in Sammlungen und ihre Literatur*. The Shepard Collection is catalogued separately.

The book is certainly one that should be in the hands of all interested in the subject of those strange wanderers from cosmical space which have survived their fiery rush through the atmospheric envelope protecting the earth from constant bombardment.

III.—A recently found Iron Meteorite from Cookeville, Putnam County, Tennessee. By George P. Merrill. Proc. United States National Museum, vol. li, pp. 325–6, pl. xxviii, 1916.

THIS meteorite, which was found in 1913, is evidently very old because it was badly weathered. Its weight before cutting was 2,132 grams. It is made up of broad bands of kamacite, between which lie thin plates of tænite. Analysis shows the percentage composition to be mainly: nickel 6, iron 61, and iron oxide 28. The meteorite is in the possession of Ward's Natural Science Establishment.

IV.—Notes on the Whitfield County, Georgia, Meteoric Irons, with new Analyses. By George P. Merrill. Proc. United States National Museum, vol. li, pp. 447–9, pl. lxxviii, 1916.

IN 1881, in the *American Journal of Science*, W. E. Hidden described an iron meteorite from Whitfield County, but gave no analysis. In 1883 C. U. Shepard described a larger mass, weighing 117 lb., from near Dalton in the same county. In 1887 George P. Kunz suggested that the East Tennessee (Cleveland) iron might be identical

with the large mass of Whitfield County iron. Examination of thin sections, however, revealed marked differences. The Hidden iron is marked by broad areas of plessite and a peculiar swelling of the kamacite bands, while between the two alloys are the regularly disposed, parallel lying tænite bands. In the Shepard iron the kamacite bands are not swollen, but show very straight borders, and the tænite bands are thinner, while it contains small, irregularly scattered, granular, and dendritic particles of schreibersite. The analyses gave similar figures, but that is not unusual in meteorites of this class. The author proposes the names Whitfield County and Dalton for the Hidden and Shepard irons respectively. The Cleveland iron also must belong to a distinct fall.

V.—On certain possible Distributions of Meteoric Bodies in the Solar System.[1] By Harold Jeffreys.

IN the third part of this paper the author deals with problems of fundamental importance to geologists, since it bears directly on the question of the initial condition of the earth, whether gaseous, molten, or solid. The following quotation from the introductory paragraph expresses the conclusions to which Mr. Jeffreys has arrived: "The objections to the Nebular Hypothesis are first summarized, and it is then shown that while the Planetesimal Hypothesis avoids most of them, it is nevertheless open to a new one, namely, that collisions between the small bodies would be so frequent, and would occur with so high a velocity, that the particles would be fused and volatilized long before accretion could produce any important effect on bodies as large as the planets. If the planetesimals be supposed to have moved initially in nearly circular orbits, this objection is avoided, but the planets are required to have always been very large."

VI.—Some Reactions involved in Secondary Copper Sulphide Enrichment. By E. G. Lies, E. T. Allen, and H. E. Merwin. *Economic Geology*, vol. xi, pp. 407–503, 1916.

THE reactions of a number of natural sulphides, viz. chalcocite (Cu_2S), covellite (Cu S), Bornite ($Cu_5 Fe S_4$), chalcopyrite (Cu Fe S_2), pyrrhotite, pyrite (Fe S_2), sphalerite (Zn S), and galena (Pb S), with copper sulphate solutions in all cases, gave rise to a copper enrichment product, and in all cases the sulphate of the metal contained in the original sulphide was formed and usually sulphuric acid as well. Cupric sulphate acts as oxidizing agent, not only at elevated but also at lower temperatures. The sulphide enrichment products are crystalline and adhere firmly to the altered sulphide as in nature. The order of stability of these products towards cupric sulphate is: chalcopyrite, covellite, chalcocite. Rise of temperature affects the rate rather than the nature of the reaction, but at high temperatures hydrolysis plays a part.

[1] Monthly Notices of R.A.S., December, 1916, p. 84.

VII.—Note on the Linear Force of Growing Crystals. By George F. Becker and Arthur L. Day. *Journal of Geology*, vol. xxiv, pp. 313–33, 1916.

THE object of this paper is to re-affirm the thesis made by the authors in 1905, viz. that the growth of crystals in saturated solution develops a linear force in the direction of the load, and that neither the magnitude of the load nor its character has any other effect than to increase solubility, and so to raise the concentration necessary for potential supersaturation and growth upon the loaded crystals. The statement had been called into question by Bruhns and Mecklenburg in 1913. The latter authors placed two crystals in a similar saturated solution, the one loaded and the other free, and remarked that the first did not lift its load. They entirely overlooked that the solubility of the loaded crystal is for most substances greater than that for the unloaded one, and further that the unloaded crystal supports weight (its own). If the supersaturation of the liquid be increased so that the free crystal cannot grow fast enough to keep the concentration down, then the loaded crystal also will grow.

VIII.—Crystals and Crystal Forces. By F. E. Wright. Journ. Washington Acad. Sci., vol. vi, pp. 326–32, 1916.

IN this short paper the author briefly rehearses what is known of the structure of crystals and of interatomic forces, and considers the methods by which further knowledge may be obtained. Incidentally he mentions that at the Geophysical Laboratory at Washington apparatus has been built or is under construction for measuring accurately the changes in the crystallographical and optical constants of crystals for temperatures ranging from − 190° to + 1600° C., and for hydrostatic pressures ranging from 1 to 2000 atmospheres. He points out the striking fact in petrology, viz. the fewness of the rock-making mineral species, especially in igneous rocks, despite great diversity in conditions of formation and in chemical composition.

IX.—Fossil Fishes in the Collection of the United States National Museum. By Charles R. Eastman. Proc. U.S. Nat. Mus., vol. lii, pp. 235–304, pls. i–xxiii, 1917.

THE fossil fish-remains in the U.S. National Museum at Washington have lately been systematically arranged by Dr. Eastman, who now publishes some notes on the collection, with figures and descriptions of a few new species. Most interesting are the fragments from old Palæozoic formations, said to be of Ordovician age, in Colorado, Montana, and South Dakota. One portion of a dermal plate, named *Astraspis desiderata*, by Walcott, consists of tuberculated polygonal tesseræ, and is compared with the dorsomedian plate of *Psammosteus* and *Drepanaspis*. It is unfortunate, however, that no new studies of the microscopical structure of this and the associated fragments appear to have been made. In the account of Devonian fish-remains there are figures of a dorsomedian plate of *Ceraspis carinata* from the

Eifel, Germany, a spine of *Heteracanthus uddeni* from Iowa, and the upper dentition of the Arthrodiran *Dinognathus ferox* from Ohio. Carboniferous species are numerous, but for the most part very fragmentary. A new species of the peculiar spine, *Harpacanthus*, from the St. Louis Limestone, Missouri, is noteworthy. Triassic fishes are well represented in the Museum, and fragments of trunk from the Kanab Valley, Utah, are referred to a new species of *Lepidotus*, named *L. walcotti*, after their discoverer. The Jurassic and Cretaceous fishes are scarcely noticed, but a supposed new species of *Notagogus* is figured from the Lithographic Stone of Bavaria. Photographs of several Tertiary fishes are published, including *Parafundulus nevadensis*, gen. et sp. nov., from the Lahontan Beds, Nevada, and *Ameiurus primævus*, sp. nov., and *Priscacara dartonæ*, sp. nov., both from the Green River Shales of Wyoming.

X.—Dentition of *Ptychodus*.

Descrizione di un notevole esemplare di *Ptychodus*, Agassiz, trovato nel calcare bianco della Creta superiore di Gallio nei Sette Comuni (Veneto). By Professor Mario Canavari. Palæontographia Italica, vol. xxii, pp. 35–102, pls. v–xiv, 1916.

THE natural arrangement of the teeth of *Ptychodus* in the jaw was first shown by specimens from the English Chalk, and next by a fine example of *P. mortoni* from the Chalk of Kansas, U.S.A. An unusually well-preserved dentition of both jaws has now been found in the Upper Senonian of Northern Italy, and is described in a beautifully illustrated exhaustive memoir by Professor Canavari.

The Italian specimen, which belongs to the variable group commonly known as *P. polygyrus* and is regarded as representing a new form or species, *P. mediterraneus*, must have originally comprised about 1,090 teeth in the two jaws. It shows the usual median row of diminutive teeth in one jaw, the relatively large median teeth in the other, and there seem to have been nine paired rows of teeth in each jaw. The former dentition measures at least 47 cm. in length by 44 cm. in breadth, while the latter measures at least 50 cm. by 42 cm. Professor Canavari thinks that the second would form a dental armature almost flat transversely, while the first would be gently arched from side to side. He therefore concludes that Dr. Smith Woodward was probably wrong in his determination of the upper and lower jaws of *Ptychodus*, and proposes to reverse them. Unfortunately, however, the supporting cartilages are only represented by fragments, so that the new specimen does not settle the question conclusively.

XI.—The Atlantic Slope *Arcas*. By Pearl G. Sheldon. Palæontographica Americana, i. pp. 100, with 16 plates.

WE welcome this, the first number of a new publication, edited by the energetic Professor Gilbert D. Harris, of Cornell University. The memoir deals with the Recent and Tertiary species of the Lamellibranch *Arca*, found on the east coast of North America, and includes mention of Cretaceous species from elsewhere and of

Caribbean species. Each of the known species is described and compared with allied forms. The editor lays great stress on the illustrations. One or more specimens of each species have been photographed so as to bring out the diagnostic character, and Dr. Sheldon has spent two years in obtaining photographs which could be reproduced without retouching. These, as well as photographs of drawings previously published by Dall and others, have been mounted on a background apparently of dark American cloth, and reproduced in half-tone as quarto plates. Professor Harris holds that such plates are "practically as good as museum specimens for critical study", and that the publication of works of this character will therefore enable satisfactory investigation to be conducted in remote institutions. Experience alone can decide whether the photographs will bear out this enthusiastic claim. At present we can only say that, while the general effect is pleasing and most of the photographs very good, still the clearest illustrations on each plate are the reproduced drawings, and the outline of some of the more shaded and rounded specimens is far from distinct in the photographs. But, granting the contention of Professor Harris, we are all the more surprised that he should have thought it advisable to reproduce such fine plates on "art" paper, and to issue a work of such importance with the sheets transfixed by wire instead of being stitched. "Time only can tell," he says, whether the experiment will prove a success. In a fight with time it is unwise to handicap oneself by using perishable materials. The subscription rate is 2 cents per page and 10 cents per plate. Hence No. 1 may be had for $3.60 (15 shillings).

XII.—Cretaceous Crabs from S. Dakota.—Some crabs from the Pierre Shales are described by Miss Mary J. Rathbun (Feb. 1917, Proc. U.S. Nat. Mus., vol. 52, pp. 385–391, pls. 32, 33). One, called after the discoverer, *Dakoticancer overana* [why feminine?], gives rise to a new superfamily of Dromiacea, the *Dakoticancroideae* [iii, at least three notes of abhorrence are needed for this mass of barbarisms], since the absence of longitudinal grooves from the sternum of the female removes it from the Dromioideae, while the sheltering orbits and the absence of *lineae anomuricae* distinguish it from the Homoloideae. "There is no complete specimen even of the carapace," but, though the description is completed, no reconstructed figure is attempted. A new species each of *Homolopsis* and *Campylostoma* are also described with care from a few imperfect specimens.

XIII.—The Flora of the Fox Hills Sandstone. By F. H. Knowlton. U.S.A. Geological Survey, Prof. Paper 98–H, pp. 85–93, pls. xv–xviii. 1916.

THE marine formation of the Fox Hills Sandstone has hitherto yielded very few plant fossils, though it lies between two Upper Cretaceous deposits which are abundantly provided with plants. The present paper gives a list and descriptions of twelve vascular

plants and one marine alga, of which only four species were previously known. The list includes one fern, one equisetum, four conifers, and six angiosperms, all save one represented by fragmentary impressions. The abundance of the alga, *Halymenites major*, Lesq., is an interesting feature, "countless thousands of specimens" being noted. A specimen of this added to the excellent illustrations would have made this first "Flora" of the Fox Hill Sandstones more complete, and more useful for those who are unprovided with the illustrations of the species first published in 1878.

XIV.—The Physical Conditions and Age indicated by the Flora of the Alum Bluff Formation. By E. W. Berry. U.S.A. Geological Survey, Prof. Paper 98-E, pp. 41–53, pls. vii–x. 1916.

THE Alum Bluff formation consists of marls and sands, of interest to palæobotanists because it represents practically the only horizon with a flora of uppermost Oligocene or basal Miocene in North America. Dr. Berry describes thirteen species, of which one is a fungus, one a Monocotyledon, and eleven are Dicotyledons. All are represented by fragmentary impressions, difficult to collect and preserve. Dr. Berry describes his method of embedding them in fresh plaster on the spot, by which means they survived the transportation to his laboratory. The most abundant species is the Monocotyledon, a palm, described as a new species of *Sabalites*. The flora is considered to be either Aquitanian or Burdigalian, "with a slight preponderance of the evidence in favour of the Aquitanian."

REPORTS AND PROCEEDINGS.

I.—The Palæontographical Society.

Annual General Meeting.

March 30, 1917.—Dr. Henry Woodward, F.R.S., President, in the Chair.

The Society having been founded on March 23, 1847, this was the seventieth anniversary. The annual report stated that the volume of monographs was again delayed by the circumstances of the time, but there was no lack of offers of palæontological work for publication, and it was expected that the forthcoming volume for 1916 would contain instalments of the monographs of Pliocene Mollusca, Palæozoic Asterozoa, Cambrian Trilobites, British Graptolites, and Wealden and Purbeck Fishes. Among members who had died during the year, Mr. C. T. Clough, Mr. Bedford McNeill, Mr. Clement Reid, and Miss A. F. Yule were specially mentioned. They were all valued supporters of the Society, and Mr. Clement Reid had done service on the Council. New members were much needed to replace the losses, and the Council appealed especially for the more active sympathy of the various Field Clubs and Natural History Societies.

Mr. H. A. Allen, Mr. E. Heron-Allen, Rev. H. N. Hutchinson, and Mr. C. T. Trechmann were elected new members of Council;

Dr. Henry Woodward, Mr. Robert S. Herries, and Dr. A. Smith Woodward were re-elected President, Treasurer, and Secretary respectively.

In a brief address, the President referred to the fact that when the Society was founded it was anticipated that all the British fossils could be described and figured in about twenty-five years, whereas the long series of fine volumes published during seventy years had only made a good beginning of the task.

II.—Geological Society of London.

1. *February* 28, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communication was read :—

"Fourth Note on the Piltdown Gravel, with Evidence of a Second Skull of *Eoanthropus dawsoni*." By Arthur Smith Woodward, LL.D., F.R.S., V.P.G.S. With an Appendix on the Form of the Frontal Pole of an Endocranial Cast of *Eoanthropus dawsoni*. By Professor Grafton Elliot Smith, M.A., M.D., F.R.S.

Excavations last summer round the margin of the gravel-pit at Piltdown (Sussex) supported the conclusion that the deposit is a varied shingle-bank, and that the three layers containing Palæolithic remains and derived Pliocene fossils are approximately of the same age. Many elongated flints and pieces of Wealden sandstone were observed in the bottom sandy clay with their long axis more or less nearly vertical. No teeth or bones were found, but one nodular flint obtained from the same layer as *Eoanthropus* seems to have been used by man as a hammer-stone. This is not purposely shaped, but merely battered along faces that happened to be useful when the stone was conveniently held in the hand.

In the winter of 1915 the late Mr. Charles Dawson discovered in a ploughed field, about a mile distant from the original spot, the inner supraorbital part of a frontal bone, the middle of an occipital bone, and a left lower first molar tooth, all evidently human. These are rolled fragments, and the first and third may be referred with certainty to *Eoanthropus dawsoni*; but it is doubtful whether they represent more than one individual. In mineralized condition they agree with the remains of the type-specimen. The piece of frontal bone exhibits the characteristic texture and thickness, with only a very slight supraciliary ridge, and a small development of air-sinuses. The occipital bone is somewhat less thickened than that of the original specimen of *Eoanthropus*, and bears the impression of a less unsymmetrical brain. The external occipital protuberance is a little above the upper limit of the cerebellum, as in Neanderthal man; thus differing from the condition both in *Eoanthropus* and in modern man. The lower molar is exactly similar to the first lower molar of *Eoanthropus* already described, but is more obliquely worn by mastication. Detailed comparison shows that this tooth is human, differing essentially from that of a chimpanzee in its more hypsodont crown, thicker enamel, and less prominence of the neck over the root.

The occurrence of the same type of frontal bone with the same type of lower molar in two distinct localities, adds to the probability of their belonging to one and the same species. With these remains were found brown flints in great abundance, and one rolled portion of a lower molar tooth of *Rhinoceros* in the same highly mineralized condition as the derived Pliocene teeth at Piltdown.

In an Appendix, Professor G. Elliot Smith expresses the opinion that the endocranial cast of the fragment of frontal bone presents features more primitive and more ape-like than those of any other known member of the human family.

---

2. *March* 14, 1917.—Dr. A. Smith Woodward, F.R.S., Vice-President, in the Chair.

The following communication was read:—

"The Carboniferous Limestone bordering the Leicestershire Coalfield." By Leonard Miles Parsons, D.I.C., B.Sc., F.G.S.

The inliers of Carboniferous Limestone situated along the northern border of the Leicestershire Coalfield crop out in two well-defined series—a Western series composed of almost horizontal beds exposed by stream-erosion, and an Eastern series in which the limestone is highly inclined and complicated by faulting. The thinly-bedded limestones, shales, and dolomites of the Western inliers are of a slightly higher horizon than that of the uppermost beds of the more massive dolomites seen at Breedon and Breedon Cloud farther eastwards. In no part of the district is the base of the Carboniferous seen, although borings have shown that the limestone rests upon pre-Cambrian rocks in the neighbourhood of Charnwood Forest.

The dolomites of the area yield evidence of two distinct periods of dolomitization—one pre-Triassic, the other subsequent to the Trias. During the former period the bulk of the rock was dolomitized.

The fauna of the limestones and dolomites indicates the presence of palæontological horizons ranging from D_1 to D_2–D_3 inclusive. The D_1 portion of the sequence, consisting of thickly-bedded dolomites without chert, contains a fauna similar to that of the Caldon Low facies of the south-western part of the Main Midland Province, the rare species *Productus humerosus* being found at Breedon and Breedon Cloud.

Unlike the rocks of the D_1 subzone of Derbyshire, the corresponding beds in Leicestershire contain no igneous rocks equivalent to the "Toadstones". Higher dolomites with chert, equivalent to the cherty limestones of Derbyshire, yield a D_2 fauna, which somewhat resembles that of the localized development of the *Lonsdaleia* subzone in the south-western part of the Midland area, in the region of Waterhouses.

A typical D_3 development is not present in Leicestershire, although the upper barren dolomites of Ticknall may represent part of the *Cyathaxonia* subzone of other districts.

The Pendleside Beds are poorly represented by about 30 feet of blue shales, which are succeeded conformably by the Millstone Grit.

3. *March* 28, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The President announced that the Council had awarded the Proceeds of the Daniel Pidgeon Fund for the present year to Arthur Holmes, D.I.C., B.Sc., F.G.S., who proposes to conduct researches in connexion with the Geology of the Dartmoor Border, around Okehampton and Belstone.

The following communication was read:—

"The Carboniferous Limestone Series on the South-Eastern Margin of the South Wales Coalfield." By Frank Dixey, M.Sc., F.G.S., and Thomas Franklin Sibly, D.Sc., F.G.S., University College of South Wales and Monmouthshire, Cardiff.

The outcrop dealt with extends from the valley of the Ewenny River near Bridgend (Glamorgan) to that of the Ebbw River at Risca (Monmouth), a distance of about 19 miles from west-south-west to east-north-east. It is traversed by the Rivers Ely, Taff, and Rhymney.

Traced north-eastwards along this outcrop, the Carboniferous Limestone Series suffers much attenuation, and becomes mainly dolomitic, as shown by the officers of H.M. Geological Survey during the recent re-survey of the coalfield.

The table on p. 230 summarizes the succession in the western part of the district.

The *Lonsdaleia* subzone (D_2) has not been recognized, and if represented, it is probably incomplete. Contemporaneous dolomitization is of comparatively small vertical extent.

At Risca the total thickness has diminished from 2,700 feet to 800 feet, made up as follows:—

	Feet.	
$C_2 + S_1$), C_1, Z	675	Main Limestone.
K	125	Lower Limestone Shales.
	800	

There the Main Limestone is almost wholly dolomitic, and nearly barren of fossils. Its lower portion consists of crystalline dolomites, which represent contemporaneously altered standard limestones. Its upper portion, composed of dolomite mudstones with bands of crystalline dolomite and a very small thickness of calcitic oolite and calcite mudstone, is a *Modiola* phase extending from some level in C_1 up into S_1. The Lower Limestone Shales maintain a normal character.

The great reduction of thickness is due to two factors, in about equal degree:—

1. Unconformable overstep by the Millstone Grit. This cuts out the *Dibunophyllum* beds and the Main *Seminula* Zone. (Overstep is very gradual along most of the outcrop, but it becomes rapid at those points where the zones of the Carboniferous Limestone swing more sharply north-eastwards.)
2. Attenuation of the surviving zones. (This is rapid in the area east of the Taff.)

SYNOPSIS OF THE SUCCESSION IN THE WESTERN PART OF THE OUTCROP (WEST OF THE CREIGIAU FAULT).

	ZONE OR SUBZONE.		APPROXIMATE THICKNESS IN FEET.	
UPPER AVONIAN.	*Dibunophyllum* Zone[1] (?) D_2 (in part). D_1	Limestones including pseudobreccias.	600 (seen)	Main Limestone.
	Main *Seminula* Zone S_2.	*Modiola* phase, characterized especially by limestones with pisolitic structures. *Seminula* Oolite.	550 to 600	
	Upper *Caninia* Zone C_2+S_1.	Limestones, including much oolite. *Modiola* phase.[2]	350	
LOWER AVONIAN.	Lower *Caninia* Zone C_1.	*Caninia* Oolite. *Laminosa* Dolomite. (γC_1) Crinoidal limestones.	550	
	Zaphrentis Zone Z.	Crinoidal limestones and dolomites: cherts near the base.	250	
	Cleistopora Zone K.	(K_2) Shale with thin limestones. (K_1 or K_2) Crinoidal limestone and oolite. (K_1)[3] Shales and limestones.	300 to 350	Lower Limestone Shales.

[1] Present only in the area west of the Ely River. [2] Detected at one locality only (Miskin).
[3] Correlation inferred from the development east of the Taff, where the Lower Limestone Shales are better exposed and K_1 is found to contain a *Modiola* phase characterized by limestones of *a*-type.

The change of lithological and faunal character in the zones which escape overstep is due to :—

3. Progressive increase in the vertical extent of contemporaneous dolomitization ; supplemented, in the area east of the Taff, by a great development of *Modiola*-phase deposits in which dolomite mudstones predominate.

The outcrop now described supplies, therefore, a key to the remarkably attenuated development of the Carboniferous Limestone Series which is known to prevail on the eastern and north-eastern borders of the coalfield. Overstep and actual thinning are both operating in a north-easterly direction to produce great attenuation.

The unconformity between the Carboniferous Limestone and the Millstone Grit is doubtless due to the earth-movement which caused flagrant unconformity between Lower and Upper Carboniferous in the Forest of Dean.

A detailed description of the lithological and faunal succession is given. The physical features of the outcrop are described, and attention is drawn to the remarkably perfect adjustment of minor drainage-lines to geological structure. The paper is illustrated by maps on which the zonal divisions are indicated, by horizontal and vertical sections, and by photographs which depict some of the most interesting features of the scenery.

---

4. *April* 18, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communication was read :—

"The Development and Morphology of the Ammonite Septum." By Professor Henry Hurd Swinnerton, D.Sc., F.G.S., and A. E. Trueman, M.Sc.

Two methods of studying the septum (not merely the suture) were used :—

1. Cleaning the face of the septum completely.
2. Filing away the surface of the whorl in successive layers, and thus making a series of sections—called septal sections—of the septum parallel to its periphery.

An instrument was designed for measuring accurately the variations in level of the face of the septum in relation to a definite datum-plane ; and also the thickness of the layers filed off from the whorl.

Dactylioceras commune, *Sphæroceras brongniarti*, and *Tragophylloceras loscombi* were chosen as types with normally shaped, greatly depressed, and greatly elevated whorls respectively.

A contoured plan of the adult septum of *Dactylioceras*, shows that half the septum lies approximately in one plane ; and that the posterior folds or lobes occupy a greater area than the anterior folds or saddles. It also confirms the view that the septum is on the whole convex forwards. In all three types the axes of the folds remain approximately at right angles to the periphery through all the changes of whorl shape. Incompletely formed septa indicate that secretion commences at the umbilical angle and at a definite distance from the preceding septum.

The examination of adult sutures of various species of *Dactylioceras* shows that the major frillings alone are of systematic importance for that genus. The variations in the minor frillings, and in the suture-line as a whole, throw light on the changes which accompany senile decline.

The second septum is remarkably like the central portion of the adult septum; but the flattened portion is relatively less extensive, the folds are sharper, and the whole septum tends to be concave rather than convex. As development advances the successive septa possess a similar resemblance to an increasing area of the adult septum. The outcome of this is, that a series of septal sections of the latter closely resembles the developmental series of the suture-line in all three types.

In no case do the septal sections show a stage comparable with the first suture-line. In *Tragophylloceras* the similarity starts not later than the seventh septum. With these exceptions, septal sections reproduce the main features in the development of the sutures with sufficient accuracy to justify their use for the same purpose, especially when the material for the study of the early stages is inaccessible.

It is possible that septal sections may also furnish the clue to the probable lines along which simplification of the suture proceeds in the retrogressive members of any stock.

Asymmetry of the septum, and of the suture-line, in ammonites is more common than is usually supposed. It may arise in two forms, namely:—

1. By the different development of the elements of opposite side.
2. By association with the lateral displacement of the siphuncle.

Asymmetry of the latter type has been considered as of systematic importance. Nevertheless, while it does occur more frequently in certain genera, as, for instance, in *Psiloceras* and *Hoplites*, it occurs not uncommonly in many other unkeeled ammonites.

III.—Mineralogical Society.

March 20, 1917.—W. Barlow, F.R.S., President, in the Chair.

A. Holmes & Dr. H. F. Harwood: The Basaltic Rocks of Spitzbergen and Franz Joseph Land, with conclusions regarding the Brito-Arctic Tertiary Petrographic Province. These rocks, which were obtained respectively from Professor Garwood and the Geological Survey of England and Wales, are very similar, not only to the basaltic rocks previously described from neighbouring localities, but also to the basalts of the whole Arctic region stretching from Dickson Harbour to West Greenland. The essential minerals are labradorite rich in the anorthite molecule, pyroxene of the enstatite-augite type, and titaniferous magnetite. The province as a whole displays significant variations both in time and space. The earliest eruptions are generally poor in alkalies, but tend to become more alkaline as the present period is approached. Thus, the later eruptions of Spitzbergen gave rise to olivine trachydiorites instead of basalt. Jan Mayen still possesses an active volcano, and its rocks are unusually alkaline

basalts. Similarly, the later rocks of Iceland, and, to a lesser extent, of Skye and the Small Isles, follow the same course. In space the most remarkable variation is seen in the distribution of titanium, the percentages of titanium oxide being high in the rocks of Greenland and the Iceland Ridge, and falling away regularly on each side. The Brito-Arctic Petrographic Province can be subdivided into five regions, viz. the British, the Icelandic (including the Faroe Islands and the Scoresby Sound district), the West Greenland, the Jan Mayen, and the Spitzbergen – Franz Joseph Land – Dickson Harbour, and the differences subsisting between them are related to the processes whereby the igneous activity was initiated. It is suggested that a petrographic province consists of a number of adjacent regions of igneous activity, in which similar rocks, or similar series of rocks, have been produced, whence it follows that the processes by which the magmas have been formed, differentiated, and intruded must be similar, and the underlying materials on which these processes have acted must also be similar.

Dr. J. W. Evans: A General Proof of the Limitation of the Symmetry Numbers of Crystals. On the assumption that crystals are composed of cells identical in all respects, then, if n be the degree of the symmetry of an axis and d an integer, the equation $\cos\frac{2\pi}{n} = \frac{1}{2}(1-d)$ must be satisfied. The only possible values of d are 3, 2, 1, 0, the corresponding values of n being 2, 3, 4, 6.

E. S. Federov: The Numerical Relation between Zones and Faces of a Polyhedron. The numerical relation shown by axes of symmetry situated in planes of symmetry pointed out by G. Cesàro in 1915 is only a particular case of the more general one deduced by the author in 1885.

A. Ledoux, T. L. Walker, and A. C. Wheatley: The Crystallization of Parahopeite. Crystals in the Royal Ontario Museum of Mineralogy from the original locality, Broken Hill, North-Western Rhodesia, are triclinic with the axial ratios $a : b : c = 0{\cdot}7729 : 1 : 0{\cdot}7124$; $\alpha = 93°\ 22'$, $\beta = 91°\ 12'$, $\gamma = 91°\ 22'$. Thirty-two forms are recorded. The crystals have perfect cleavage parallel to the brachypinacoid, and show lamellar twinning parallel to the macropinacoid. The angle of optical extinction on the cleavage is 10° with reference to the twin-lamellæ.

IV.—Edinburgh Geological Society (February 21, 1917).—"The Submarine Contours around the Orkney Islands." By Dr. Flett, LL.D., F.R.S., President of the Society. Dr. Flett pointed out that geologists were agreed that the main physical features of the north-east of Scotland were developed long before the Glacial period, and that the Orkneys were a northward continuation of the Caithness plain which had suffered depression, and had been partly overflowed by the sea. The principal sounds crossing the islands in a north-west to south-east direction were the valleys of old rivers like those of Caithness and Sutherland. At what date the land sank was not definitely established, but Orkney was probably joined to Caithness when the present assemblage of animals entered the islands. Along

the east side of the archipelago the principal submarine feature is a steep bank rising from depths of 35–40 fathoms to about 20 fathoms. It has a general N.N.E. direction and a very straight trend, and undoubtedly is a continuation of the east coast of Caithness, which is to be correlated with the great fault that winds down past Brora and Helmsdale, bringing in the Secondary rocks on its eastern side. This is distinctly a land feature now submerged. Dr. Flett showed that the land had sunk in stages; periods of rapid depression alternated with pauses when subsidence was slow. In this way he explained the origin of certain very level areas on the sea bottom, covering wide stretches around the islands. One of these submarine flats lay at a depth of 18 fathoms and the other at 8 fathoms. At different periods Scapa Flow and Kirkwall Bay were large fresh-water lakes surrounded by swampy land. These changes had taken place since Neolithic man first inhabited the islands. In Sutherlandshire the land had risen to some extent, as was shown by raised-beach platforms at 100, 50, and 25 feet above the present sea-level. It seemed in every way probable that while Scotland as a whole was rising, Orkney and also Shetland were being submerged, and the submarine flats of Orkney corresponded in origin and date to the raised beaches of the rest of Scotland.

V.—Liverpool Geological Society.

March 13, 1917.—J. H. Milton, Esq., F.G.S., F.L.S., President, in the Chair.

The following papers were read:—

1. "On an interesting Occurrence of Secondary Rutile in the Millstone Grit." By H. W. Greenwood.

The grit in which the rutile occurs forms the base of a long ridge of hill which commences about a mile north-east of Macclesfield, runs for about two miles in a northerly direction, and terminates just above the village of Bollington. The particular exposure described occurs in a quarry on the hillside overlooking Bollington. The rock contains a quantity of light yellowish interstitial decomposition product, and it is in this and also in small cavities lined with iron-stained debris that the secondary rutile occurs in little glistening grains of a brilliant pink colour, sometimes deepening to a port wine tint. In some parts of the rock the crystals occur in such quantity as to become the dominant heavy mineral. The evidence points to the rutile having been formed from the alteration of a titaniferous biotite. In addition to the secondary rutile there are also deep yellowish red usually rounded grains which form part of the original constituents of the rock. Anatase is also abundant, generally growing on leucoxene, and staurolite was also noted.

2. "A Comparison between the Structure of the Assynt District of North-West Scotland and that of the Swiss Fore Alps." By J. S. Daly, B.A.

A detailed analysis of the structure of both regions was first given, and the similarity between them then made clear in an interesting manner.

CORRESPONDENCE.

POST-GLACIAL UPLIFT IN NORWAY.

SIR,—Please add the following reference to that one already given in my review, "Irregularities in the Post-Glacial Uplift of Norway," GEOLOGICAL MAGAZINE for April, p. 174 :—

Gunnar Holmsen, "De brædæmte sjøer i Nordre Østerdalen": *Naturen*, Feb. 1917, Bergen, pp. 48–60.

This paper has just arrived: it is a little fuller in some respects than the one already cited.

LEONARD HAWKES.

EVERSLEY,
STOW PARK AVENUE,
NEWPORT, MON.

THE ALKALINE ROCKS OF SOUTH-WEST AFRICA.

SIR,—In the GEOLOGICAL MAGAZINE for December, 1915, you published a letter from me under the above title. In that letter I expressed the intention of visiting the occurrences of alkaline rocks [in the desert south of Lüderitz Bay], and of describing the rocks in detail. I was aware at the time that Professor Erich Kaiser, the distinguished petrologist of Giessen, was in South-West Africa, but I was not aware that he had come out from Europe for the express purpose of studying these very rocks. I have now returned from a visit to South-West Africa, where I had the pleasure of renewing my acquaintance with Professor Kaiser, and I learned that he has utilized his enforced leisure in the country (as a prisoner of war) by studying these alkaline rocks most minutely and mapping the occurrences on special, large scale topographic sheets prepared for the requirements of the diamond-mining companies. Professor Kaiser and Dr. Betz most kindly arranged an extensive tour for me, when I was able to visit and collect material from all the principal localities. Under the circumstances I must of course renounce my intention of writing anything more about these rocks until Professor Kaiser's memoir appears; I can only assure you that that memoir, when it does appear, will possess a quite extraordinary interest for petrologists.

S. J. SHAND.

GEOLOGY DEPARTMENT,
VICTORIA COLLEGE,
STELLENBOSCH, S.A.
February 8, 1917.

OBITUARY.

CHARLES BARRINGTON BROWN, Assoc. R.S.M., F.G.S.

BORN AUGUST 23, 1839. DIED FEBRUARY 13, 1917.

CHARLES BARRINGTON BROWN was the second son of Richard Brown, F.G.S., F.R.G.S., of Cape Breton, Nova Scotia, the

author of several papers contributed to the earliest volumes of the Quarterly Journal of the Geological Society, whose drawings of sections of the Cape Breton coal-fields are found in most geological textbooks since Lyell's *Principles*.

Born at Cape Breton, he was educated at Harvard University, and at the Royal School of Mines, London (1862–4), taking his associateship in Geology. On the recommendation of Sir Charles Lyell, a close friend of his father, he was appointed to the Geological Survey of the West Indies (Jamaica) and of British Guiana (Demerara), on which he served with J. G. Sawkins from 1864 to 1870. For the next four years, from 1870 to 1873, he was in sole charge of the Survey. His reports on the Geology of British Guiana and of Jamaica in collaboration with that geologist are still the standard works on the subject, and earned the commendation of the Governors of those colonies.

During his travels on the Potaro River, a tributary of the Essequebo, he made the discovery, in April, 1870, of the famous Kaieteur Falls, the highest known true waterfall in the world, 822 feet in height and 123 yards wide; the chief wonder of British Guiana. An account of this discovery is to be found in one of Barrington Brown's books, *Canoe and Camp Life in British Guiana*, London, 1877, and in the Journal of the Royal Geographical Society (vol. xli, 1871). This is his description of the discovery:—

"Descending the river [Potaro] rapidly all day, we came within sound of the roar of a large fall. . . . When we came to the northern end of the savanna I observed that heavy masses of vapour were drifting before the north-east wind, making the trees, grass, and shrubs on our right dripping wet. This came from the great fall, to which we were in close proximity, but which was hidden from view by a grove of trees. Making a detour to the right through this grove, we came out on the flat rocks at the head of the great fall, and walking to the edge of the precipice, down which the water was precipitated, I gazed with wonder and delight at the singular and magnificent sight that lay before me.

"Not being prepared for anything so grand and startling I could not at first believe my eyes, but felt that it was all a dream.

"There, however, was the dark, silent flow of water down which we had travelled, passing slowly but surely to the brink of a great precipice, and breaking into ripples as it approached its doom. Then curving over the edge in a smooth mass of brownish tinge, changing into snow-white fleecy foam, it was precipitated downwards into a black seething cauldron hundreds of feet below. . . . I was prepared to meet with great falls on our way down . . . but nothing of so grand and extraordinary a nature as this ever entered my mind for a moment."

Shortly afterwards he discovered the less well-known but nevertheless remarkable fall of Ourindouie, on the Ireng River, a tributary of the Rio Branco. It may be remembered that a Dr. Bovallius announced, in 1907, the discovery of a waterfall on that river "rivalling Niagara", which he proposed to call the "Chamberlain Fall". Brown, on reading this account, recognized a description of

the Ourindouie Fall, and was able to prove its identity by publishing a sketch he had made of the fall, in 1870, in the *Daily Graphic* of November 29, 1907. Accounts of this fall, and of the mysterious mountain of Roraima, which, in common with Sir Robert Schomburgk, at an earlier date, he in vain tried to ascend, are found in the above-mentioned book.

In 1873 to 1875 he was engaged in further exploration of the Amazon River and its tributaries for the Amazon Steam Navigation Company; an account of his travels is given in his *Fifteen Thousand Miles on the Amazon and its Tributaries*, London, 1878. Again, in 1887, 1889, and 1891 he examined gold placers and reefs in British Guiana, and also at other times in Surinam.

During this period, too, he was appointed by the Secretary of State for India to report on the ruby mines of Burmah, which resulted in a paper, written in conjunction with Professor J. W. Judd, which was published in the *Philosophical Transactions* of the Royal Society of London in 1896. This work is regarded as a classic contribution to the history of corundum.

Thereafter, in 1889 to 1902, he devoted his time chiefly to the mining of gem-stones in North Carolina, Ceylon, and New South Wales, at Inverell; and in later years was interested in the development of certain graphite mines in Ceylon.

Towards the latter part of his life, the hardships and vicissitudes of travel in such varying climates, and the fevers contracted on the Amazons, began to tell on his iron constitution, and it is almost surprising that he reached the advanced age of 77 years.

He had that rare quality of endearing himself to those with whom he came in contact, whatever their race or creed; and was a close associate of such men as Judd and Bennett Brough.

A lifelong friend, Dr. G. R. M. Pollard, who travelled with him in British Guiana, wrote of Barrington Brown: "There was no one more popular amongst his fellows than he, and I cherish the memories of many pleasant hours spent in his companionship. There was one characteristic that impressed everybody who came into business relationship with him, and that was his absolute integrity. His word was his bond; and his transparent honesty of purpose and fairness of dealing enabled him to manage and control, without difficulty, the many uncertain tempers of the men he had to employ in subordinate positions."

Besides contributing various papers to the Quarterly Journal of the Geological Society of London, to which he was elected a Fellow in 1879, and to the Journal of the Anthropological Society, he presented specimens, collected in his travels, to the Royal Gardens at Kew, the British Museum, and the Royal United Service Institution at Whitehall. A list of his published works is appended (p. 238).

After a life full of years useful to the cause of science and to our knowledge of the world, he passed away peacefully, in London, in his 78th year.

C. B. B., JUN.

A List of Published Works by C. Barrington Brown.

1869. Reports on the Geology of Jamaica, or Part II of the West Indian Survey; by James G. Sawkins, F.G.S., with contributions by C. B. Brown. London.
1871. Report on the Kaieteur Waterfall of British Guiana; with a map: Journ. Roy. Geogr. Soc., vol. xli.
1872. "Indian Picture Writing in British Guiana": Journ. Anthrop. Inst. Gt. Britain and Ireland, vol. ii.
1875. Reports on the Physical, Descriptive, and Economic Geology of British Guiana; by Charles B. Brown, F.G.S., and J. G. Sawkins, F.G.S. London.
1877. *Canoe and Camp Life in British Guiana.* London.
1878. *Fifteen Thousand Miles on the Amazon and its Tributaries*; by C. Barrington Brown, A.R.S.M., and William Lidstone, C.E. London.
1879. "On the Tertiary Deposits on the Solimões and Javary Rivers in Brazil"; with an Appendix by R. Etheridge, F.R.S., F.G.S.: Q.J.G.S., vol. xxxv.
1879. "On the Ancient River Deposit of the Amazon": Q.J.G.S., vol. xxxv.
1888. Report on the Ruby Mines of Burmah, June 15, 1888.
1889. "Rocks and Minerals of British Guiana": Journ. Roy. Agric. & Comm. Soc. British Guiana, vol. iii.
1896. "The Rubies of Burma and Associated Minerals: their occurrence, origin, and metamorphoses: a contribution to the history of Corundum"; by C. Barrington Brown, A.R.S.M., F.G.S., and J. W. Judd, C.B., LL.D., F.R.S., F.G.S.: Phil. Trans. Roy. Soc., vol. clxxxvii.

RICHARD HILL TIDDEMAN, M.A. (Oxon.), F.G.S., etc.

Born February 11, 1842. Died February 20, 1917.

We have to record the loss of Mr. Richard Hill Tiddeman, M.A., F.G.S., who from 1864 to 1902, for thirty-eight years, held the post of Geologist on the Geological Survey of England and Wales, during which time he served under four successive Directors: Murchison, Ramsay, Geikie, and Teall.

His principal work was in connexion with the Carboniferous Rocks of Yorkshire and the neighbouring counties of Cumberland and Lancashire, on which he was occupied for about twenty years. Later he did good work in North Wales. He was recognized as one of the leading authorities on these deposits and his knowledge was always willingly imparted to other workers, to whom he was an ideal companion and guide. In appreciation of his services the Yorkshire Geological Society elected him their President in 1914, and during his term of office he was a most valuable guide and instructor in the field and at the Society's meetings.

In presenting the Murchison Medal to Mr. Tiddeman in 1911, Professor Watts, the President of the Geological Society, said: "Ever since the beginning of Mr. Tiddeman's work for the Geological Survey on the borders of Yorkshire and Lancashire he has kept his eyes open to the observation of exceptional facts, and his mind employed in working out explanations for them. The excavation of the Victoria Cave, Settle, in which he took so active a part gave us valuable information on the history of the Pleistocene Mammalia; his work on the glaciation of North Lancashire still remains 'a model

and a basis for glacial work all over the country'; his observations on the faunas of the Carboniferous 'Reef-knolls' of the North of England have put on record a wealth of observation and reasoning which will contribute no little to the solution of the problems presented by these remarkable structures; and his researches upon the raised beaches of Gower covered with glacial deposits have extended the area of known Pleistocene movement beyond Yorkshire and Cork."

A Yorkshire geologist writes of him in the *Naturalist* (April, 1917, p. 142): "Mr. R. H. Tiddeman, so well-known and beloved by Yorkshire hammer-men, has passed away. He was a quiet and conscientious worker, and made many firm friends in the county in which he did so much good work."

On his retirement from the Survey in 1902, he took up his residence in Oxford, but he was a frequent attendant at the meetings of the Geological Society in London, and was a member of its Council. He leaves a widow and two daughters.

Mr. Tiddeman was not a voluminous writer, but he contributed to many of the Survey memoirs, maps, and other publications. The Geological Survey memoir *On the Water-supply of Oxfordshire* bears his name. The following papers are also by Mr. Tiddeman:—

1872. "On the Evidence for the Ice-sheet in North Lancashire and adjoining parts of Yorkshire and Westmoreland": Q.J. Geol. Soc., vol. xxviii, pp. 471–91.

1873. "The Older Deposits in the Victoria Cave, Settle, Yorkshire": GEOL. MAG., pp. 11–16.

1894. "Carboniferous Trilobites from the Banks of the Hodder, near Stonyhurst, Lancs," by Henry Woodward [with "Notes on the Geology", by R. H. T.]: ibid., pp. 481–2.

1900. "On the Age of the Raised Beach of Southern Britain as seen in Gower": ibid., pp. 441–3.

1901. "On the Formation of Reef-knolls": ibid., pp. 20–3.

HARRY PAGE WOODWARD, J.P., F.G.S.,

ASSOC. MEM. INST. C.E.

BORN MAY 16, 1858. DIED FEBRUARY 7, 1917.

WITH deep regret we received, by the mail of March 31, the announcement of the death on February 7 at Perth, West Australia, of Harry Page Woodward, eldest and sole surviving son of Dr. Henry Woodward, the Editor of this Magazine and for many years Keeper of the Geological Department in the British Museum.

H. P. Woodward was educated at University College School, London, and at the Royal College of Science, South Kensington, where he studied geology under Professor Judd, and field-work with his cousin Mr. Horace B. Woodward, F.R.S., of the Geological Survey of England and Wales. In 1883, upon the recommendation of Sir A. Geikie, K.C.B., and Professor J. W. Judd, C.B., he was appointed Assistant Government Geologist to the Colony of South Australia, where he did valuable work for three and a half years. In 1886 he returned to London and spent a year in the Metallurgical Laboratory

of the Royal College of Science. In December, 1887, he was appointed by the Secretary of State for the Colonies to the post of Government Geologist for Western Australia, where he has ever since resided. In 1895 he resigned his appointment as Government Geologist and entered the service of Messrs. Bewick, Moreing & Co., the Colonial Government conferring upon him the title of Honorary Consulting Geologist and Mining Engineer to the Colony. In 1883 Mr. H. P. Woodward was made a Justice of the Peace for the Colony. In 1897 he severed his connexion with the firm of Bewick, Moreing & Co. and commenced business as a Consulting Mining Engineer in Perth. After eleven years of unofficial geological work in West Australia Mr. Woodward, in 1906, rejoined the Government Geological Survey under Mr. A. Gibb Maitland, a post he continued to hold up to the time of his death, which occurred (after a brief illness) on February 7 last.[1]

On December 31, 1890, Mr. Woodward married Ellen Maude, the second daughter of the Hon. J. F. T. Hassell, of Albany; he leaves a widow and three sons, the second of whom has recently joined the Australian Army.

MISCELLANEOUS.

Geological Map of City of Dublin Area.

The Ordnance Survey has published, at the price of 3*s.*, a Geological Map of Dublin, on the scale of six inches to one mile, prepared by the Geological Survey of Ireland (Department of Agriculture and Technical Instruction). It extends from Clontarf and Sandymount to Castleknock and Drimnagh, thus including the City, Phœnix Park, and a large residential district. The superficial deposits, boulder-clay, gravels of various types, and materials on the area intaken from the sea, are shown by colours, the underlying limestone rock appearing only in a few rare patches. Hence the map is of special service to architects and engineers, and to all who are concerned with house-sites and town-planning. The topographic basis is identical with Sheet 18 of the Ordnance Survey map of the County of Dublin, and hence a map of the city is provided on a large scale in addition to the geological information. Among the points of interest brought out on the map are the courses of the partially concealed streams that run into the Liffey on the southern side; the great plateau of boulder-clay that masks the old bank of the Liffey in the region of Phœnix Park; and several of the gravel mounds of the Greenhills esker, which have supplied so much material for roads and building purposes. The alterations, partly due to human and partly to marine agency, in the coastline at the west end of Dublin Bay, are well shown by the insertion, in red dotted lines, of the coast, as represented in a map by Bernard de Gomme, published in 1673. The district is described in detail in the illustrated Memoir of the Geological Survey on the country around Dublin (1903; price 3*s.*).

[1] For a fuller notice of H. P. Woodward's life and work see the GEOLOGICAL MAGAZINE for September, 1897, pp. 385–8 (with a portrait).